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A SIMPLE METHOD DEVISED BY F. C. PENROSE FOR FINDING THE ORBIT OF A HEAVENLY BODY BY A GRAPHICAL PROCESS.*

ERIC DOOLITTLE.

FOR POPULAR ASTRONOMY.

INTRODUCTION.

It is well known to astronomers that if the position which a moving comet or planet occupies among the stars is observed at three different times, then from these three measures alone the exact size, form and situation of the entire path can be determined. If the measures could be made with perfect accuracy, and if it were not for the slight perturbations to which the moving body is subjected, it would be possible to predict from the three observations the position of the body in space and also its apparent situation among the stars at any desired date, either in the past or in the future.

The formulas by which this remarkable result is achieved were first developed completely by the illustrious Gauss, upon the discovery of Ceres in 1801. Modern treatises on orbits have so perfected these formulas and supplemented them by such complete numerical tables to aid the astronomer in his computations that this branch of astronomy seems to have been brought almost to a state of perfection.

But to the amateur astronomer, who may be interested in such a beautiful mathematical development but who has perhaps neither a knowledge of calculus nor time to devote to long computations, the whole subject must be a sealed book. He may know that from a few evenings' observations astron-

* "On a Method for finding the elements of the Orbit of a Comet by a Graphical Process", by F. C. Penrose. *Monthly Notices of the Royal Astronomical Society*, Vol. 62, page 68. The original paper was rewritten and expanded for Chamber's Astronomy, Vol. I. The present paper is merely a detailed explanation of this method, with its obvious extension to include the orbits of asteroids.

omers can find out exactly in what orbit a heavenly body is moving, but without higher mathematics he cannot learn how it is done. For every such reader we will fully explain a short and very simple graphical process. We will describe the form in which observers who measure comets and asteroids with their telescopes publish their measures in the astronomical journals and how from these and a few quantities taken from the *American Ephemeris*, (or better, from the *Perliner Jahrbuch*), he may find a very approximate orbit, in fact, an orbit sometimes nearer the true one than the orbits first published, and which are derived by computation from three observations.

Although we here describe the graphical method because we believe that it will interest amateur astronomers, we think that it should be of use to those familiar with the usual methods of computing orbits as well, and this for the following reason. When a new comet is discovered, the computer begins to determine its orbit by applying a long succession of mathematical formulas, using in his computations the measured positions in which the comet was seen in the sky. But instead of these positions, he ought to use in his formulas the positions in which the comet would have been seen if it had been observed from the center of the Earth instead of from the Earth's surface. The times of observation used in the computation also should not be the times recorded by the observer at his telescope but the times at which the light left the comet, because these latter are the times at which the comet was in the directions observed. Now neither the positions of the comet as seen from the Earth's center nor the time occupied by light in coming from the comet to the Earth can be found until the distances of the comet from the observer have been determined, and these distances are not known until the computation is almost completed. Accordingly the computer, using the observed positions and recorded times, carries on the computation for finding an approximate orbit until he has performed perhaps four-fifths of the numerical work required and then he corrects the observed positions and recorded times and begins the computation all over again. This work of finding the first approximate orbit can be performed much more rapidly by the graphic process than by computation; in the course of computing some twelve or fifteen orbits, we have found it very valuable for this purpose and believe that it merits more attention than it seems to have received.

To clearly understand the following paper the reader must have some knowledge of elementary trigonometry, and he must

know enough of geometry to follow the proofs of a few simple relations between lines drawn in space. We assume that he knows the meaning of the terms Right Ascension, Declination, Latitude, and Longitude. While the right ascension and declination of a moving body are always obtained by observation, it is the corresponding latitude and longitude which, except in some very special cases, are always used as a basis for computing orbits. To obtain these last from the observed right ascension and declination we require three formulas of spherical trigonometry which we shall solve by the use of logarithms. This first step of changing right ascension and declination into latitude and longitude is by far the longest computation in connection with the graphical method and the only one which requires any knowledge of mathematics beyond the formulas dealing with the right angled triangles of plane trigonometry.

Before we begin to describe the graphic method in detail, we must first explain for the beginner some of the elementary relations and laws upon which it is founded.

CONSTRUCTIONS IN THE PLANE OF THE ORBIT.

1. The Path of a Comet about the Sun.—It is now believed that a comet is merely a cloud of little particles out in space, which ages ago began to feel the pull of our Sun and to fall toward that body. At first it moves very slowly, but its velocity rapidly increases, not only because of its stored up velocity, (as is the case with falling bodies near the Earth's surface), but also because as it draws nearer to the Sun the pull upon it grows very rapidly stronger in accordance with Newton's Law.*

If at the beginning the cloud and Sun were both at rest in space, the cloud would, of course, fall directly onto the Sun. But as both bodies are drifting through space, the latter with a velocity of eleven miles a second, the probability of this ever occurring is extremely small. The chance is so great as to be almost a certainty that the cloud, or comet, will miss our Sun, but swing around it and recede into space, never to be seen by us again.

Thus, were the Sun at *S*, Figure 1, and the cloud at *A*, the pull would take place along the line *SA*. A few days later,

* See a most interesting paper by Professor Comstock in *Popular Astronomy*, Vol. 10, page 169. It is here shown that if comets come from the region of the fixed stars, (which is not entirely certain), then the time from when they begin to move toward our Sun as a center until they actually reach us is about 11,000,000 years.

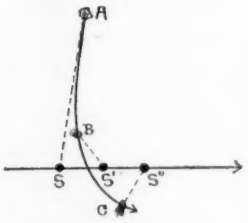

FIGURE 1.

when the Sun had reached S' and the comet B, the attractive force would be exerted in the direction $S'B$ and so on both the direction and the intensity of the force continually changing. Now it can be proved that the resulting path in which the comet moves will be a curve lying wholly in a plane passing through the center of the Sun and that its orbit will always be one of three kinds of curves known as Conic Sections. We will now consider these three curves in detail.

2. To draw the Path of a Comet about the Sun when two positions of the Comet in its path are given.—The path of nearly all comets about the Sun is, as nearly as it can be determined, a curve called a *Parabola*. This is a curve each point of which is equally distant from a fixed point, (called the *Focus*), and a fixed straight line,(called the *Directrix*). Thus, the curve MN, Figure 2, is a parabola of which S is the focus and DD' is the directrix. If A, B, C, and P are points on the curve, then according to the definition, $AS = Aa$, $BS = Bb$, $CS = Cc$, $PS = Pp$, etc. It is evident that the point P is half way between S and DD'.

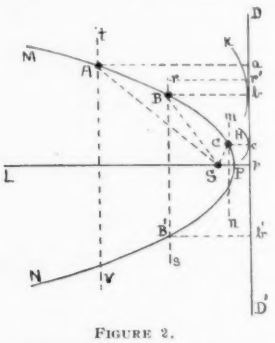

FIGURE 2.

All parabolas are of exactly the same shape, just as all circles are of the same shape; a large parabola is merely a magnified image of a small one. The reader can draw an accurate parabola as follows.

First draw a line DD' for a directrix and choose a point S for a focus. Then draw a series of lines mn, rs, tv, etc., each parallel to the directrix, and to find the point at which the parabola crosses any one of these lines, for example rs, choose a radius $SB = rr'$ and with S as a center describe a circular arc cutting rs in B and B'. Then B and B' will be two points of the desired curve, since by the construction $SB = rr' = Bb$ and $SB' = Bb'$. Similarly, any number of parallel lines may be drawn and any number of points found, after which a smooth curve may be drawn through these points.

The Sun always lies at the exact focus of a parabolic path described by a comet. The line, $LSPp$, drawn through the Sun

perpendicular to the directrix is called the *Axis* of the parabola, and the point P, in which the axis cuts the curve is called the *Perihelion*. Finally, the distance SP from the Sun to perihelion is called the *Perihelion Distance*; it is always represented by the letter q.

If the distances and directions of the comet from the Sun at two different times are known, it is easy to construct from these the entire path. Thus, if B and C are two positions of the comet, it is only necessary to describe two circular arcs, one having B as a center and a radius BS, and the other having C as a center and a radius CS, and then to draw a straight line DD' tangent to these two arcs. This line will evidently be the directrix, and having now the directrix and focus we construct the entire parabola by locating points on it as above described.

3. To draw the path of a body moving about the Sun in a nearly circular orbit when three positions of the body are given. —The paths of the planets, asteroids, and periodic comets are all varieties of the curve called an *Ellipse*. This is a curve such that the sum of the distances of any point in it from two given points, (called the *Foci*), is constant.

Thus, the closed curve of Figure 3 is an ellipse, of which S and F are the two foci, and hence according to the definition, $AS + AF = BS + BF = CS + CF$ etc. An ellipse can readily be constructed by fastening the ends of a string, FBS, at the foci, pressing a pencil point firmly against the string, and moving the pencil about the foci, keeping the string taut throughout the motion.

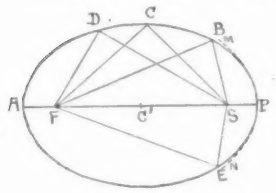

FIGURE 3.

The Sun always lies exactly at one focus of an elliptic orbit; the line ASP passing through the foci is called the *Major Axis*; the point of intersection, P, of this line with the curve which is nearest the Sun is called the *Perihelion*, and the quotient obtained by dividing the distance, $C'S$, from the center of the ellipse to the Sun by the half major axis, $C'P$, is called the *Eccentricity*. Hence writing $C'P = a$ and eccentricity $= e$, we have, $e = \frac{C'S}{a}$.

When the Sun is near the center of the ellipse, so that the distance $C'S$ is small in comparison with $C'P$, the eccentricity is small also, and the ellipse very closely resembles a circle. This is the case with the planetary orbits, all of which look almost

exactly like true circles with the Sun a short distance out of the center.

If we have given three positions of a planet or asteroid and it is desired to draw the elliptic orbit through them, we therefore begin by describing a circle *M*, Figure 4, through these three points. The Sun will not lie in the center of this circle, (unless the eccentricity of the true orbit happens to be exactly zero), but the second focus and the true center of the ellipse may be very approximately found as follows.

Mark the center *m* of the arc *AC*, Figure 4, and draw the diameter *mD*. It is a property of the ellipse that lines, *Sm* and *Fm*, drawn from the foci to any point of the curve make equal angles with the tangent to the curve at that point, that is, *SmT'* = *FmT*, and hence *SmO* = *OmF*. Now the tangent to the circle at *m* practically coincides with that to the ellipse, hence draw *mK* making the angle *KmO* = *OmS* and the focus *F* will lie somewhere on this line. We also have *Fm* + *mS* = *SP* + *PF* = *PL*, and *PL* is very nearly equal to the diameter *mD* of the circle; hence *Fm* = *mD* — *mS*, (very nearly). Therefore lay off *DR* = *mS* and with *m* as a center and a radius *mR* describe an arc cutting *mK* in *F*. Then *F* will be very approximately the position of the second focus.

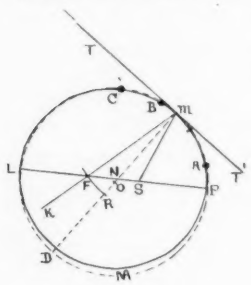

FIGURE 4.

Having the two foci, draw the ellipse as above described, mark its center *N*, and find its eccentricity by the relation $e = NS \div NP$.

4. To draw the path of a periodic comet when three positions of the comet are given.—The periodic comets move in ellipses of high eccentricity similar to the curve drawn in Figure 3. If now we construct a parabola *MN* on this same figure, having its focus at *S* and its perihelion at *P*, we will find that the ellipse will lie wholly within the parabola but that the two curves will very nearly coincide in the neighborhood of *P*. If the comet has been observed at at least one return, so that we know its period, and if, (as is usually the case), our observations lie not far from perihelion, we find the true orbit by the following method.

We first draw a parabola through the observed positions nearest perihelion as in (2), and as the parabola and the ellipse nearly coincide at these points we assume that the position of *P* so determined is the same as the perihelion of the elliptic orbit.

We then find the half major axis PC' of the orbit by applying Kepler's Third Law: $(PC')^3 \div$ (Distance from Earth to Sun)^3 =(Comet's period in years)$^2 \div$ (Earth's period)^2, from which, if the comet's observed period is represented by P and the distance from the Earth to the Sun taken as our unit of distance,

$$PC' = \sqrt[3]{P^2}.$$

Thus, for example, with Encke's comet, $P = 3.303$ years, or $P^2 = 10.910$, so that the half major axis of this orbit $= PC' = \sqrt[3]{10.910} = 2.218$ times the distance from the Earth to the Sun.

Having found PC' in this way, we mark the position of the center at C' and that of the second focus at F and draw the ellipse as before.

It when drawing the orbit of a recently discovered comet we find that positions far from perihelion fall decidedly within the parabolic arc, we recognize that an elliptic orbit is indicated, but the period in the orbit is unknown. In this case we locate perihelion by a parabola as usual and then draw in an ellipse by trial which shall pass as exactly as possible through all the observed points. The most convenient way to do this is by the use of a silk thread and two sewing machine needles. The thread is knotted and passed through the eye of one of the needles, which is then inserted at S; the other end of the thread is passed loosely through the eye of the other needle and held firmly by the left hand. By trying various positions along the line $C'A$ for the second needle, and each time allowing enough length of thread, FBS, between the needles to correctly locate P, a position of F will soon be found for which the curve will pass accurately through all of the given positions. A slight groove should be cut in the side of the lead point to prevent its slipping off of the thread.

If there are no observations near perihelion, this point cannot be located by a parabola, but the first needle having been fixed at S as before, the second one must be moved to various positions and the length of the thread changed by trial until an ellipse is found which passes through all of the points.*

* In the rare case in which as we recede from perihelion we find that the points lie farther and farther *outside* of the parabola, we recognize that we have a hyperbolic orbit, and to draw this, we proceed as follows.

The hyperbola is a curve the distance of any point of which from the focus divided by its distance from the directrix is a constant number greater than

5. We have now shown how when two or three positions of a body are given the path may be drawn. But if an accurate orbit is desired, several positions should be used if they are available and these observations should be separated by as long an interval of time as possible. If we are assuming a parabolic orbit it will be found that on account of unavoidable inaccuracies, both in the observations and in the drawing, the positions of the directrix determined as explained in (2) from the points taken in pairs will not exactly agree. We can draw this line in a sort of average position among the various determinations, or, what is still better, we can locate it and draw the

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unity called the eccentricity. Thus, in Figure 5, MN is a hyperbola whose focus is S and directrix DD' and hence $\frac{AS}{Aa} = \frac{BS}{Bb} = \frac{CS}{Cc}$ etc. $= e$.

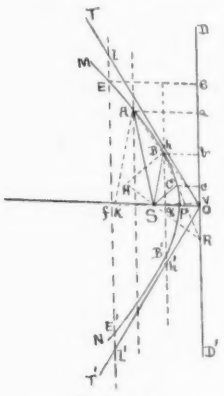

FIGURE 5.

Having given the focus S and the three positions A, B and C we must first find the directrix. To do this, draw BH parallel to CS and make $BH = BS$; join BC and HS and produce these lines until they meet in R. Similarly from A draw AK parallel to BS, making $AK = AS$ and join AB and KS, producing these lines until they intersect in V. The straight line drawn through R and V will then be the directrix. For, if we draw Aa, Bb and Cc perpendicular to this line, we have from the triangles BHR and CSR, $\frac{BH}{CS} = \frac{BS}{CS} = \frac{BR}{CR}$; and similarly $\frac{Bb}{Cc} = \frac{BR}{CR}$

Hence, $\frac{BS}{CS} = \frac{Bb}{Cc}$, or $\frac{BS}{Bb} = \frac{CS}{Cc}$.

Similarly, from the triangles along AV, $\frac{AS}{Aa} = \frac{BS}{Bb}$. Hence $\frac{AS}{Aa} = \frac{BS}{Bb} = \frac{CS}{Cc}$, and hence DD' is the directrix.

The next step is to locate points on the curve. From S draw SO perpendicular to DD'; from any one of the positions, as B, draw BB' parallel to DD', lay off gh and gh' equal to BS, and draw the lines OT and OT' through h and h'. Now draw any line ll' parallel to DD' and with $fl = fl'$ as a radius and S as a center describe an arc cutting ll' in EE'. These are points of the desired curve since from the triangles lfO and hgO we have $\frac{lf}{fO} = \frac{hg}{gO} = \frac{BS}{Bb} = e$. But $lf = SE$ and $fO = Ee$, hence $\frac{SE}{Ee} = e$, and E is a point of the curve.

Having found as many points as we please in this way, we draw a smooth curve through them. The value of e is then found, and the distance PO is measured. The quotient obtained by dividing PO by the quantity $(e - 1)$ is called the half-major axis of the hyperbola and represented by a. We, therefore, find a from the relation, $a = \frac{PO}{e - 1}$.

PLATE III.

S N

COMET MOREHOUSE (*c* 1908).

Photographed by J. H. Metcalf, Taunton, Mass., November 16, 1908.
(Exposure $5^h\ 35^m - 6^h\ 35^m$)

parabola from the first and last positions only and then transfer the curve to a sheet of tracing cloth; by placing this tracing over the drawing with its focus on the Sun we can so shift its position that it will pass reasonably well through all the points.

In nearly all cases a parabolic curve may be fitted to the observations in this way, but if this is found to be impossible on account of the points falling continually farther inside or outside of the parabola as we recede from perihelion, we must then conclude that the path is an ellipse or a hyperbola and construct the corresponding curve as explained in (4).

To be continued.

COMET (MOREHOUSE) 1908 *c*.

JOEL H. METCALF.

For Popular Astronomy.

Comet Morehouse has been photographed here every clear night when the Moon did not interfere. The result is a collection of pictures numbering 104, half of which were taken with the 12-inch of 87.5 inches focus and half with a very short focus lens made recently by myself; its aperture is a little over 6¾ inches and its focal length about 20 inches.

The exposures ranged from one to two hours.

The photographs taken with the 12-inch show a vast amount of detail within a few degrees of the head of the comet. The short focus lens gives the fainter parts of the tail at a greater distance from the head.

It would be out of the question for me to try to enter into any detailed study of these photographs as my time does not permit and I am satisfied that there ought to be some general cooperation between astronomers by which all the good photographs could be brought together and studied together.

There are a few points I would like to note however.

First there are very many condensations in the tail of this comet which are so distinct and sharp as to be capable of fairly accurate measurement. These condensations can often be identified on at least three plates with intervals of a day between them. For instance the deformation of the tail which was so striking on Oct. 15 is also visible on my plates of Oct. 16 and 17.

A measurement of the same part of the condensation on all

three nights gives material for determining the velocity of the condensation for two successive days.

If this mass were acted upon by the pressure of light to produce its repulsion from the Sun one would expect a greater rapidity on the second day than the first. This is not, however, borne out by the plates of October 14, 15 and 16, which show a slight decrease in the motion of the second day in the proportion of 30 to 28. I do not lay any emphasis on this apparent decrease as it may be due to the rough measurement but in any case it precludes any marked increase of velocity.

These measurements also show that the condensation of October 15 must have left the coma about October 15 0^h Gr. M.T.

In a large number of these photographs, the detail near the head shows a very marked twisting like that of a piece of twine or cord. The effect is what one would expect from a slowly turning pin wheel in motion. This is as though the coma was revolving in a plane perpendicular to its motion. This effect is however, by no means, alway found and in very many cases there is not the slightest suspicion of it.

The transformation of the coma with its great number of envelopes never twice alike is as striking as the changes in the tail.

In September and October, the small camera revealed a strong tendency for the tail to be curved first concave in the direction of the comet's motion and then perhaps the next night convex in the same direction. Thus the tail would be bowed now toward the north and now toward the south.

As the comet became more active in November, this tendency was not so conspicuous. (The plates taken October 24, 1908, and taken October 30, 1908 are among the last to show this.)

An impression which the variety of these plates make upon one is that in spite of their protean forms, there are at bottom only two types of tail, one characterized by long narrow and nearly straight rays which from their form and sudden changes of intensity seem like magnetic or electrical effects of the same general nature as the aurora. The other without distinct or sharp rays is characterized by a curdled appearance which is irregular or "puffy" in form like the smoke rolling out of a tall chimney when the fireman has just put on fresh coal. Or perhaps the analogy is more like the cloud forms of our own sky, the first type being like the high cirrus or "mares' tails" of a coming storm. The second like the cirro-cumulus clouds which

have been curdled or coagulated when at a lower level they are rippled into distinct forms.

In our own atmosphere these changes from alto-cirrus to curro-cumulus must be due not alone to the forces acting on the condensed inverture the currents which draw them out but also in the physical condition of the water itself. Either a change from solid to liquid or a change in the size of the particles of water, probably principally the later.

A study of the changes in this comet while it may not disprove that the repulsion due to the pressure of light has a prominent place in the production of its tail, certainly shows the problem to be a most complex one, the complete solution of which will demand many other factors. As illustration of the two types of tail to which I refer I enclose two photographs M. A. 685 taken Oct. 31, 1908 showing the second type, M. A. 697 taken Nov. 16, 1908 showing the first type. The change from one type is often very abrupt certainly within an interval of 24 hours.

Taunton, Mass.,
December 12, 1908.

A WELL-DEFINED AURORAL ARCH.

S. J. CORRIGAN.

For Popular Astronomy.

On the evening of Monday, Nov. 16, 1908, my attention was attracted at about 9:15, central standard time, to a peculiarly interesting display of the aurora, which although—during the time that I observed—it did not exhibit any of the darting and drifting rays, or streamers, that often render this phenomenon a most striking spectacle, was the more instructive by reason of the absence of these brilliant, but confusing, features, because the auroral arch itself was thereby more clearly defined, so that some very accurate measurements of its position, dimensions and height above the Earth's surface were thus made possible. I have, during the course of many years, observed a great number of auroral displays, particularly from this city, St. Paul, Minn., (Latitude 44° 53′ N; Longitude 93° 05′ W) but in none have I seen the auroral arch so well defined in all its parts, as it shone, on the date aforesaid, with a steady, bright yellow light, it presenting the appearance of an incandescent solid.

My measurements gave 14°.5 as the mean-altitude (H) of the

vertex, or highest part, of the arch the azimuth of the westerly base whereof was 59°.5 from north toward west, while the azimuth of the easterly base was 73°.5 from the north toward the east, one-half the difference between these two azimuths or 7°, being, almost exactly, the declination of the magnetic-needle from the north point toward the east, at St. Paul, Minn., at the present time,—a very significant fact and one of several, indicating the electro-magnetic nature of the aurora. The arch being thus perpendicular to the magnetic meridian and spanning 133° of the northerly horizon, the azimuth (A), on each side of said meridian, was 66°.5 in this case. That eminent authority on this subject, Prof. H. A. Newton, as well as other physicists, regarded the auroral arches as arcs of circles approximately parallel to the Earth's surface, the center of these circles being the magnetic pole, or *pole of verticity*, where the dip of the magnetic-needle is 90°, this pole, in the northern hemisphere, being approximately in latitude 70° North and longitude 96°.7 West. If we designate the angular distance of any place of observation from the aforesaid pole by d, the vertical height (h) of the plane of the circle of which the arch is a segment, above the Earth's surface, is determinable through the following trigonometrical equations due to Prof. Newton:

$$\sin \phi = \sin d. \cos A. \operatorname{cosec}. (H + d)$$
$$\tan c = 2 \sin H. \sin \phi. \sec^2 \phi$$
$$h = R (\sec c - 1)$$

in which the altitude (H) of the vertex of the arch was in this case, 14°.5, as aforesaid, the azimuth (A) on each side of the magnetic meridian 66°.5, the distance (d) 25° while the value of the mean radius (R) of the Earth is 3958 miles, whence it appears that, in this case, the height (h) of the auroral circle was 40 miles which includes, as I have demonstrated, nearly 99 per cent of the mass of the whole terrestrial atmospheric envelope, it being also very nearly the height (45 miles) which the laws of refraction indicate as the *sensible* upper limit of the atmosphere although, in a very tenuous state, the latter extends above to the height of 250 miles, according to my demonstration set forth in another part of POPULAR ASTRONOMY. The quantity (c) determinable by its tangent in the second of the group of equations above set forth, is the distance, in angular measure, of the points directly under the visible ends of the arch, which are also at the height of 40 miles since the plane of the arch is parallel, throughout, to the Earth's surface, the value of (c) in this case having been 8°.17′, or about 575 miles

in linear measure, to the northwest and northeast of St. Paul, Minn., the westerly *apparent* end of the arch having been over latitude 49° N; longitude 103° W, and the easterly end over latitude 47° N; longitude 82°.5 W, while the linear distance to a point under the middle of the arch, and which is determinable through the expression $\frac{h}{\tan H}$, was, in this case, 155 miles a little to the northeast of this city and nearly over Duluth, Minn., the visible segment of the auroral circle thus extending from the junction of the boundaries of North Dakota, Montana and Assiniboia, eastwardly across Lake Superior to a point, in the province of Ontario, about 200 miles north of Georgian Bay, the circle of which this arch was a segment enclosing not only the north magnetic pole but also the North American *focus* of maximum magnetic force (Latitude 52° N, Longitude 90° W) which is also the pole of *greatest cold* on this continent.

According to my theory, as set forth in another part of POPULAR ASTRONOMY, auroral effects are caused by the disruption of the molecules of the tenuous gases of the upper atmosphere and the gathering together of the dissociated atoms of these molecules particularly toward the magnetic poles, this dissociation and recombination giving rise to electro-magnetism, and the intense atomic movements, or vibrations, being productive of the peculiar luminous phenomena observed. This disruption is caused by radiations from the Sun, consequent upon the ejection of matter heated, more or less, above the normal temperature of the radiating solar surface matter, which is only a little above the parabolic, or disruptive, limit, the excess of temperature being ordinarily only sufficient to cause auroral effects at an average height of 20–40 miles above the Earth's surface, but an extraordinary outburst of enormously heated matter from below the solar photosphere may suffice to cause extensive disruption even at the Earth's surface, in which case the height of the auroral region becomes zero the arch then extending, perpendicularly to the plane of the magnetic meridian, from the easterly to the westerly horizon, and almost through the zenith, as indicated through the equations for the height of the arch, and there are then severe magnetic-storms and earth-currents.

Through the aforesaid equations it appears that an arch closely approximating 180° in length, thus spanning nearly the whole sky and passing nearly through the zenith, indicates, at once, that the auroral action extends to the Earth's surface and that the place of observation is within its sphere; but when the

amplitude of the arch is considerably less—for example 133° as on Nov. 16, 1908—a higher altitude of the middle of the arch indicates, on the other hand, a *greater* height of the aurora above the Earth's surface. The former condition, although quite rare, does sometimes exist, as indicated in a communication, to *General Notes* in Aug.-Sept. 1907 number of POPULAR ASTRONOMY, from Frederic Campbell, President, Department of Astronomy, Brooklyn Institute, on the auroral arch of August 1903, in which note he also referred to a like phenomenon on Sept. 7, 1871, and to one in July 1907, while in the same number appeared a note from A. B. Hervey, of Bath, Maine, describing one on July 3, 1907, and also that of Aug. 1903 which was widely extended, and observed from Maine to Montana. It should be remarked that although the arch on Nov. 16, 1908 was composed of dissociated atmospheric matter just above Duluth, Minn., and the other points named above, it would not be seen, there, near the zenith, but at an altitude not very different from that at St. Paul, or about 14°.5, because in any given display the arch is composed of matter over different localities, being, in reality, a different arch, in each case, so that ordinary parallactic measurements do not furnish a correct method of determining the height of an aurora, and the use of this method has led to erroneous results in the past. It should also be noted that, by reason of parallactic displacement, auroral rays proceeding, from the plane of the arch, toward the Earth, and southward over the place of observation, must appear to radiate *upward* from the arch, and toward the zenith, although the real path slopes *downward* toward the observer. Apparent lateral motion of the rays may also result from this cause.

The density (D) of the atmospheric gases at any given height (h) above the Earth's surface, relative to the normal density at said surface, (Barometer 30 inches, or 760 millimeters of mercury, Temperature 32° Fahr., or 0° Centigrade) is determinable through the following equation of my theory of gases:

$$\log \frac{1}{D} = 0.058255 \left(1 + \frac{h}{R} \right) \cdot h ;$$

in which R represents the mean radius of the Earth, which is 3958 miles. This equation gives 0.00419 as the relative density (D) at the aforesaid height of 40 miles, and this density corresponds to a barometric pressure of three and one-sixth millimeters of mercury at the normal temperature, (0.° C) a significant fact as the following statements will demonstrate. In No.

106 of *Astronomy and Astro-Physics* (June 1892) there appeared a transcript of a paper read before the National Academy of Science at its Washington meeting, in April of that year, the author being Prof. M. I. Pupin of the Department of Electrical Engineering, Columbia College, New York City, on the subject "Electrical Discharges in Poor Vacua and Coronoidal Discharges." This paper described the results of the experiments, and the effects caused by inductive electrical discharges upon air confined in glass bulbs and at different degrees of exhaustion, from a good vacuum at, and about, two millimeters, to a poor one at sixty millimeters, a series of six photographic plates beautifully illustrating the luminous effects at the several stages of exhaustion accompanying the paper in the publication, aforesaid.

The luminous appearances at low pressures—two or three millimeters—are identical with those of the Aurora Borealis, while at pressures approximating sixty millimeters, they were decidedly similar to those presented by the solar corona and also by the tails of comets, even to the pulsations often noticed in these phenomena; but what is most pertinent, in this connection, is the author's reference to the appearances when the vacuum was *about three millimeters* in a certain case which as he stated showed that something of the nature of *a dissociation of the gas molecules* was going on along the path of the discharge." He also remarked that "both the color, and the lateral motion, of the discharge reminded me very much of the aurora borealis of Feb. 13, 1892," and further; "in this connection, it is well to remark that when the electromotive force is below the critical point, this auroral discharge can be started by powerful disruptive discharges of a Leyden jar, in its vicinity. This in connection with observations on coronoidal discharges, given in the latter part of this paper may, perhaps, furnish a clue in tracing the connection between sun-spots and auroral discharges." Now, the density of the atmospheric gases at a height of 40 miles, at which the auroral arch was on Nov. 16, 1908, being three and one-sixth millimeters and that in Prof. Pupin's experiment aforesaid, about three millimeters, this remarkable coincidence constitutes, practically, an experimental demonstration of my theoretical conclusions as to the electrical nature and height of the aurora. A density of sixty millimeters, the highest employed by the experimenter in this case, corresponds, under the same conditions of temperature, to a height of 20 miles, as deduced through my equation for the

relative density (*D*), above set forth, (40–20) miles being the height in most cases although the auroral action must obviously operate up to the upper limit of the atmosphere (250 miles), and in the ether beyond, even to the radiating surface of the Sun itself; but beyond the height of 40 miles the atmospheric gases in that upper region, and the gaseous matter constituting the luminiferous ether beyond, are so extremely tenuous that the luminous effects of the Sun's electro-magnetic radiations thereon must be correspondingly feeble and appear much as the Zodiacal Light which, according to my theory, is a result of the same cause and mode of operation. While, in the case of this, and every other, mooted scientific question, it is well to be very conservative, it seems to me that there is now, and for a considerable time past has been, evidence quite sufficient to warrant positive and irrefutable statements as to the electro-magnetic nature of the aurora, its cause and the *modus operandi* in its development.

Saint Paul, Minn.,
December 12, 1908.

ANCIENT HISTORY AND WORSHIP OF THE PLANET VENUS.

IRENE E. TOYE WARNER.

FOR POPULAR ASTRONOMY.

Venus, the beautiful sister-planet of the Earth, was distinguished among the early Greek poets by the name of Hesperus and Vesper when she appeared as an evening star, and as Phosphor or Lucifer, "the light-bearer", when she became visible as a morning star before sunrise. Another appropriate title was Calliste "the most beautiful." She enjoys the honor of having been the only planet mentioned by Homer in the *Iliad*, where he calls her "Hesperus, the fairest star in the heavens."

The Assyrians considered the planet Venus to be especially under the rule of the goddess Ishtar, or Istar, with whom she is often identified, the sixth month Elul being dedicated to her. Ishtar, called Nana by the Babylonians, was their "queen of love and beauty" but unfortunately her cult was generally of a debasing nature and her worship far from elevating. She was sometimes associated with the great god of Assyria, Asshur, as the leader of armies, "the fortunate," "the happy," "the great goddess," and other exalted titles being showered upon her.

On one Babylonian inscription she is addressed as "Ishtar, eldest of heaven and Earth, raising the face of warriors." Judging by the great number of times her name is inscribed on the cuneiform tablets recently discovered, Ishtar must have been a favorite object of worship in Assyria and Babylonia. She had important temples at Nineveh, Arbela, Erech, and other ancient towns. That of Nineveh was restored by Samsivul and rebuilt by Assurbalid, king of Assyria in about B. C. 1400, Shalmaneser I B. C. 1300, Tugulti-ninip B. C. 1271, Assur-risilim B. C. 1150, Assur-nazir-pal B. C. 885, Shalmaneser II B. C. 860, and other Assyrian kings also restored the temple of Ishtar at Nineveh and frequently dedicated votive dishes and the spoils of war to this goddess. We are told that Tiglath-Pileser carried off twenty-five images of the gods of the countries north of Assyria and put many of them in the temple of Ishtar in about B. C. 1117.

The Ishtar of Arbela was chiefly invested with a character of war and battle. Assur-bani-pal (B. C. 668 to 626), the Sardanapalus of the Greeks, and the greatest of Assyrian monarchs, being a renowned warrior, was very naturally most devoted to her service. On one occasion, before he fought with Teumman, king of Elam, he celebrated splendid rites to the "Lady of Arbela" praying and weeping before her and reminding her of his good deeds in restoring her temple. He relates that Ishtar heard his prayer and told him to be of good courage and he should gain the victory. He also invaded the country of the Elamites because they refused to deliver up an image of the goddess Nana (or Ishtar) which they had formerly carried away from Erech in B. C. 2280 and which was said to have been worshipped in Shushan, the capital of Elam, for 1,635 years. Ishtar is supposed to have appeared by night to the soldiers and promised to march in front of them; this inspired the army and a great victory was the result. The image of Nana was taken from Shushan B. C. 645 and on the first day of the month Kislev was restored to its temple in Erech with great rejoicing. Assur-bani-pal then rode in triumph to her temple at Nineveh where he alighted from his chariot and bowing with his face to the ground adored the gods, ascribing his victory to Asshur and Ishtar. In an inscription of this king discovered at Kouyunjik we read "The goddess Nana who for these 1,635 years had been desecrated and had dwelt in a place unsuitable to her, until the days of her captivity were full. Her journey to Erech, her entry to Bit-anna she has commanded to my majesty."

The planet Venus, as the *evening* star, was identified with the Ishtar of Erech; and as a *morning* star, with Anunit goddess of Akkad. On the cuneiform inscriptions, Ishtar is sometimes called the daughter of Sin the moon-god, and sister of Shamas the sun-god. This seems most natural as Venus is next in order of brilliancy to those glorious orbs; in other places, however, she is termed daughter of Anu, a god of the first triad of Assyrian divinities whose exact meaning is not known with any degree of certainty,—Lenormant believing that Anu represents the primordial chaos, or matter without form; G. Rawlinson, that Anu was god of the Earth, corresponding to the Greek Pluto; and yet another authority, that Anu was the god of heaven. Ishtar is frequently coupled with Nebo (Mercury), the Assyrians evidently having noticed the position of these planets moving in an orbit between Shamas, the Sun, and the Earth. In some places Nebo is called the child of Ishtar.

In the cuneiform inscriptions of Babylonia there is a very interesting account of the war in heaven after the creation of the Earth, in which Ishtar is mentioned as having been appointed by Bel to assist the Sun and Moon to control the lower part of heaven, "with Anu to the government of the whole heaven he set them up. To the three of them the gods his children, *day and night to be united* and not to break apart, he urged them." This seems to be a poetical expression of a scientific fact, for Venus is ever, comparatively speaking, near the Sun, rising and setting, as a rule, but a short time before or after him.

Ishtar is invoked on a votive inscription of Shalmaneser I B. C. 1300 when he restored her temple at Nineveh. He says "The prince who comes after me, who my cylinders shall see and restore to their place, may Ishtar bless him; and whosoever destroys my records, may Ishtar curse him, and his name and his seed from the country root out."

All through the Assyrian records we find continual allusions to "Ishtar of Nineveh, Ishtar of Arbela" as having led the victorious armies of the kings; and captives, weapons captured in battle, images of the enemies' gods, and votive dishes, were frequently dedicated to her honor. Assur-bani-pal commences every tablet describing his conquests by stating that the goddess Ishtar had commanded him, and ends by ascribing his victory to her power.

The Phœnicians had temples in some of their cities dedicated to her worship under the name of Astarte, but this title is much

more frequently applied to the Moon than to Venus and is probably borrowed from the older divinity of Phœnicia.

The Hindus knew her as Sukra "the brilliant;" in a tropical climate when the air was clear and still, she must indeed have been a lovely object, fit for the homage and admiration of all nations. The ancient Mexicans who were much given to solar worship also had temples to Venus under the name of Citlal Choloha, and the volcano Citlal-tepetl was called after her "the mountain of the star." Amongst the natives of South America she was known as "the star who announces the day,"—evidently a star heralding the return of the sun-god was regarded with greater love than one that ushered in the night—a night, we must remember, completely dark except for the natural lights of heaven.

In Slavonic legends it is said that the Moon (who is masculine) was cleft for his infidelity to the Sun (feminine), because he had deserted her and fallen in love with Jutrzenka, "the morning star;" the Slavs apparently thought her little inferior to the two more brilliant orbs. Perhaps this legend refers to a very close conjunction of the Moon and planet?

The ancient Arabians had many temples in honor of the planets or *chunnas-stars*, and Venus under the name of Zoharah had one called Beit Ghomdan, in Sanaa, the capital of Jaman. It was destroyed by the Khalif Othman when the Mohammedan Faith, after a hard struggle, triumphed over idolatry. There is a legend, taken by the Arabians from the Persian, about this planet which narrates that two angels were sent down from heaven to judge mankind. This they did justly for some time until Zoharah or Venus, took the form of a beautiful woman and appeared before the angels to tempt them. They fell in love with her, whereon she flew up again into heaven followed by the angels who were refused admission, until, on the intercession of a pious man, they were allowed to choose either punishment in this world or in the next. They selected the former and were imprisoned in Babel where they are to remain until the day of judgment. The fable relates that if a man wants to learn magic, he may visit their abode and listen to their voices but cannot see them.

Venus was probably the first of all the planets to attract the admiring gaze of primitive men. Her surpassing lustre would easily lead them to believe that she was next in importance to the Sun and Moon, being queen of the dawn or twilight, as the Sun was king of the heavens by day and the Moon their queen

at night. Also her close attendance on the central orb would greatly enhance their idea of her power and loveliness; so it is little to be wondered at that she always received more than her share of the almost universal reverence accorded to the heavenly bodies.

To Pythagoras, about B. C. 540, or according to some authorities, Parmenides, about B. C. 513, belongs the honor of having definitely determined the identity of Lucifer and Hesperus which until his time had probably been regarded by the Greeks and Romans as two distinct planets. She was undoubtedly, I believe, the first of the planets to be recognized as such; the discovery of Mercury must have been made a good deal later as the difficulty of observing him is so much greater owing to his closer proximity to the Sun, rare visibility, and smaller aspect.

The Venus of the ancient world has passed away with her temples, her worshippers, and her old mystical power and we turn with a feeling almost like regret, to the Venus of to-day, shorn as she is of much that made her so beautiful to the eyes and poetical imaginings of the nations of antiquity. We might indeed exclaim in the words of the biblical writer "How art thou fallen from heaven, O day star, son of the morning"! But although she has lost her divine personality and the adoration of the pagans, nothing can deprive her of the material loveliness she displays as she glows in the twilight, the supreme queen of the stellar host. In the drama of "Cain" written by Byron we read:—

> "There is a wisdom in the spirit, which directs
> To right, as in the dim blue air the eye
> Of you, young mortals, lights at once upon
> *The star which watches, welcoming the morn* . .
> The *symbols* of the Invisible are the loveliest
> Of what is visible; and *yon bright star*
> *Is leader of the host of heaven.*"

Bristol, England.

AN ASTRONOMICAL THEORY OF THE MOLECULE AND AN ELECTRONIC THEORY OF MATTER.

Solar and Terrestrial Physics Viewed in the Light Thereof.

SEVERINUS J. CORRIGAN.

FOR POPULAR ASTRONOMY.

Part IV. (Continued.)

THE TERRESTRIAL ATMOSPHERE. ITS VOLUME, EXTENT, DENSITY, PRESSURE, TEMPERATURE AND THE METEOROLOGICAL EFFECTS CAUSED THEREIN BY THE SOLAR ELECTRO-MAGNETIC RADIATIONS.

The factor for the correction due to decrease of the force of gravity with the altitude is, obviously, $\left(1 + \frac{h}{R}\right)^2$, in which R represents the mean radius of the Earth, or the radius of a sphere whose volume is equal to that of the terrestrial spheroid. The values of the equatorial and polar radii of the Earth are, according to Clarke, respectively, 20,926,062 feet and 20,855,121 feet, so that the mean radius (R) is 20,897,548 feet, or very nearly 3958 miles; and, therefore, a complete expression for the density at different altitudes (h), relative to the normal density at the surface of the Earth—which density is taken as 1—is the following—

$$\log \frac{1}{D} = 0.058255 \left(1 + \frac{h}{3958}\right)^2 \cdot h. \qquad (5a)$$

Now, by means of this equation, the altitude at which the density, pressure and temperature of the atmosphere just equals the corresponding quantities in the case of the gaseous matter called the "luminiferous ether"—which altitude is that of the upper limit of the atmospheric envelope of the Earth—can be found through a short, tentative process, if we know the density of said ether relative to the density of the atmosphere at the Earth's surface and under the normal conditions of pressure and temperature.

The density of the ether, I have found as described in my treatise on the constitution and functions of gases, and its numerical value is $\frac{1}{1.412 \times 10^{16}}$, and, using this value in Equation 5*a*, the altitude of the upper limit of the atmosphere is

found to be 245 miles above the surface of the Earth; but this is true only under the condition that the Earth's gaseous envelope is unaffected by the heat received from the Sun, and is the limiting altitude only when what may be called the "intrinsic temperature" (the nature of which will be explained on subsequent pages) is considered, and when the increase of temperature due to solar heat is taken into account, the atmospheric envelope is found to be expanded to such a degree that the limiting altitude is 250 miles above the surface of the Earth which, in this connection, is regarded as a sphere; but, since the atmospheric envelope is composed of fluid matter which rotates with the rotation of the Earth upon its axis, the surface of this envelope must be approximately that of an oblate spheroid, and conform, in general, to the figure of our globe.

If the density did not decrease with the altitude, but were the same at all altitudes, the observed atmospheric pressure at the surface of the Earth, and the known weight of a cubic foot of air, would indicate, as the limiting height of the atmosphere, only about five miles, but the well-known laws of refraction, when applied to the case of the light of celestial bodies, which is radiated through the atmosphere, point to an altitude of about 45 miles as the *sensible* upper limit of the atmospheric envelope; but this is only the altitude at which the density can cause easily measurable effects and, obviously, is not the true limiting altitude, because it is well-known that luminous meteors are cosmical bodies which have their progress in their orbits around the Sun partially arrested by their passage through the Earth's atmosphere, the lost motion being converted into heat which renders the meteor visible, and as they are sometimes quite brilliant when at an altitude of 100 miles, or even more, the atmosphere must extend, with sensible density, to that distance, at least, above the Earth's surface,—and it has been estimated by competent investigators that, in an attenuated condition, it may extend to a height of 200 miles.

The facts which I have just stated have been determined by eminent physicists, are well-known to all who have made this subject a study, and are of great interest and importance in connection with the question of the proper determination of the altitude of the upper limit of the terrestrial atmosphere, which, according to the computation that I have made as described on a preceding page, is 250 miles,—a value which, as indicated by observation, is true to within considerably less than a mile.

By means of Equation 5*a*, I have computed the relative density

at each of the several altitudes set forth in the first column of Table I following, these densities being given in the second column thereof, while the third contains the values of the weight of a cubic foot of air—or its density at the normal surface temperature—corresponding to each altitude, the normal relative humidity of the air at 32° Fahrenheit, being taken at 59 per cent.

As is well-known, moist air is specifically lighter than dry air, and the following considerations enable one to easily find the weight of a cubic foot of air at 32° Fahrenheit whose relative humidity is 59 per cent. The effect of the tension of aqueous vapor upon the normal barometric pressure is, as stated on a preceding page, 0.0199 of a pound per square inch, or nearly 0.0013492 of the pressure aforesaid, and this latter would be also the porportional quantity by which the normal weight of a cubic foot of dry air should be reduced in order that we may obtain the corresponding weight in the case of air having the relative humidity aforesaid, if the density of aqueous vapor were equal to that of the atmospheric gases under the same conditions of pressure and temperature; but since the density of this vapor is only the .623 part that of air, the quantity 0.0199 aforesaid is only the .377 part of the whole tension corresponding to the weight of the vapor in the volume of air, and therefore the factor for the reduction of the weight of a cubic foot of dry air to that of an equal volume of moist air, in this connection, is 2.6525, and multiplying the proportional number 0.0013510 above set forth, by this factor, there results the number 0.0035835, which represents the proportional part of the normal weight of a cubic foot of dry air which must be deducted from said weight in order that we may obtain that of an equal volume of moist air whose relative humidity is 59 per cent.

The normal weight of the aforesaid volume of dry air being 0.0807226 of a pound, an equal volume of moist air under the normal conditions is found to be 0.0804338 of a pound, and multiplying each value of the relative density given in Table I by this last mentioned quantity, we have the results set forth in the third column of that table; then, by means of a careful and extended interpolation to the middle of each interval, in the case of the densities set forth in the last mentioned column, I have obtained the results which appear in the fourth column, each being the mean density, in pounds, of a cubic foot of moist air, for the whole interval just above the line upon which the value of the relative density is set forth.

The question of temperature must now be considered, and it is an all-important one in this connection, because, although the mean densities have been determined as above described, the respective pressures, and, therefore, the *theoretical* normal pressure at the Earth's surface, which is to be compared with the *observed* normal pressure, for the purpose of verifying the whole work, are functions of the temperature.

A well-known expression for the relation between the pressure (P), density (D), temperature (T) and weight (W), in the case of gases, is the following:—

$$P = DT = W,$$

whence it appears that the three quantities represented by P, D, and W are equivalent only when $T = 1$; or, in other words, only when the absolute temperature at any altitude is equal to the normal surface temperature, and since, as is well-known, the temperature decreases rapidly as the altitude increases, the densities in Table I do not represent pressure or weight, the values of which quantities must be determined from those of the densities by the application of the temperature factor as indicated in the expression last set forth, and which leads to the following—

$$T = \frac{D}{P}, \tag{6}$$

or, since $P = D^{1.5}$, the equivalent equation—

$$T = D^{0.5} \tag{7}$$

expresses the relation aforesaid.

Now, according to the hypothesis advanced in my treatise on the constitution and functions of gases, the intrinsic temperature of any gas is due to the collisions of the rapidly revolving atoms of the gaseous matter, *inter se*, its value depending upon the number of impacts occurring in unit time, and also upon the velocity with which each of said ultimate particles is moving; and since the atoms constituting a molecule are, according to my hypothesis, revolving around the center of that molecule, in obedience to that law of central forces which is known as "Kepler's third law," it follows that the angular velocity, or number of revolutions in unit time, which is one factor in the production of temperature, is inversely proportional to the 1.5th power of the radius of the atomic orbit—which is also the radius of the molecule—and, therefore, directly proportional to $D^{0.5}$, because the density (D) of the gaseous matter in any volume is inversely proportional to the volume of each molecule, or, in

other words, to the cube of the radius,—this cube representing the reciprocal of the relative density designated by D.

TABLE I.

Altitude in Miles.	Relative Density.	Density per Cubic Foot. (Pounds.)	Density per Cubic Foot for Interval. (Pounds.)	Relative Temperature. (Absolute.)
0	1.000000	0.0804238	....	1.000000
1	0.874410	0.0703320	0.0755314	0.914414
2	0.764489	0.0614908	0.0660413	0.836079
3	0.668297	0.0537536	0.0577363	0.764386
4	0.584127	0.0469835	0.0504684	0.698776
5	0.510488	0.0410605	0.0441093	0.638740
5.2	0.500000	0.0402169	.....	0.629960
6	0.446073	0.0358793	0.0385464	0.583809
7	0.389734	0.0313477	0.0336806	0.533554
8	0.340456	0.0273847	0.0294249	0.487574
9	0.297379	0.0239193	0.0257035	0.445526
10	0.259714	0.0208898	0.0224499	0.407064
20	0.066540	0.0053521	0.0141930	0.164260
30	0.016817	0.0013526	0.0036294	0.065638
40	0.004192	0.0003372	0.0009153	0.025998
50	0.001031	0.0000829	0.0002277	0.010203
60	0.0002500	0.00002011	0.0000559	0.003969
70	0.0000598	0.00000481	0.0000137	0.001529
80	0.0000141	0.00000113	0.0000033	0.000582
90	0.0000033	0.00000026	0.0000008	0.000219
100	0.0000008	0.00000006	0.0000002	0.000082
125	1.782×10^{-8}	1.433×10^{-9}	3.466×10^{-8}	0.000006822
150	3.862×10^{-10}	3.106×10^{-11}	8.198×10^{-10}	0.000000530
175	7.665×10^{-12}	6.150×10^{-13}	1.584×10^{-11}	0.000000039
200	1.386×10^{-13}	1.115×10^{-14}	3.100×10^{-13}	0.000000003
245	7.082×10^{-17}	5.712×10^{-18}	9.330×10^{-15}	0.00000000002
The ether,	5.712×10^{-17}	5.712×10^{-18}	.....	0.00000000002

But temperature depends, as aforesaid, not only upon the number of revolutions and consequent impacts in unit time, but also upon the fundamental velocity in each revolution, which velocity measures the *momentum*, or intensity, of each impact, and is taken as unity for gases at the normal pressure and temperature at the Earth's surface, as has been stated. For different normal densities the fundamental orbital velocity is different; the less the density the greater, obviously, is the molecular radius which is also the radius of the atomic orbit, and the fundamental orbital velocity is, consequently, less, it being, as shown in my treatise aforesaid, proportional to $D^{\frac{1}{6}}$, this being, therefore, the

factor which must be introduced into Equation 6 in order to take into account the effect of variation in the fundamental, linear, orbital velocity of each atom, caused by variation of the normal density, or, in other words, by differences in the radii of the normal atomic orbits in any volume of any gas; and therefore we have $T = \frac{P}{D} \cdot D^{\frac{1}{6}}$; or, since $P = D^{1.5}$, the following equivalent expression—

$$T = D^{\frac{2}{3}}, \tag{8}$$

which is the final and complete expression for the absolute normal "intrinsic temperature" of any gas.

The normal temperature at the Earth's surface is regarded in this connection as 32° Fahrenheit, or 491°.652 absolute—and this being taken as 1, the relative temperature (T) for the relative density (D) corresponding to each altitude is computed by means of Equation 8, and the results are set forth in the fifth column of Table I, given in a preceding page.

Taking the arithmetical mean of the mean densities in the fourth column of Table I for each group of intervals segregated by the horizontal spaces, the result in each case is the mean density, in pounds, of a cubic foot of the atmospheric gases for each group, and multiplying each of these last mentioned densities by the number of cubic feet in the interval between the concentric spheres surrounding the Earth and including each group, the result is the density, in pounds, of all the air—including its normal quantity of aqueous vapor—within the intervening space.

The number of cubic feet in each interval is easily found by means of the mean radius of the Earth, derived from Clarke's values of the equatorial and polar radii of the terrestrial spheroid, as described on a preceding page, its value being 20,902,356 feet.

In Table II following, the first column contains the several intervals, in miles; in the second column is set forth the number of cubic feet in each intervening space, the number being, in each case, expressed, for the sake of convenience, in powers of 10, and in parts thereof; in the third column are the mean densities, in pounds, of a cubic foot of air for each group, and in the fourth column the total density—expressed in the same unit—for each interval, and this density would also be the *weight* per interval, if the atmospheric gases were, at all altitudes, at a temperature the same as the normal surface temperature of 32°

Fahrenheit. But, as has been shown on a preceding page, gaseous pressure and the density and weight of gaseous matter are not always synonymous terms, the pressure being a function of the temperature, and since the latter decreases from its normal value of 491°.652 Fahrenheit absolute at the Earth's surface, down to the temperature of the luminiferous ether (which temperature, according to my determination set forth in my treatise aforesaid, is only the $\frac{1}{100000000}$ part of a degree Fahrenheit above what is called "absolute zero"), the relative temperature by which the sum of the densities set forth in the last column of Table II must be multiplied in order that we may obtain the theoretical normal barometric pressure is, obviously, the mean relative temperature of the whole mass of air, which is that corresponding to the relative density 0.5 at an altitude of 5.2 miles, as indicated in Table I.

This mean, relative temperature, as computed through Equation 8, and set forth in the last column of Table I, is 0.629960, and multiplying the densities given in the last column of Table II by this number, the result summed up is the total *weight*, in pounds avoirdupois, of the atmosphere with its normal quantity of aqueous vapor. Dividing this total weight by the number of square inches on Earth's surface, *i. e.*, by the number expressed by 7.902455×10^{17}, I have obtained the value of the *theoretical* normal atmospheric pressure per square inch, for sea-level, in latitude 45° and for a normal surface temperature of 32° Fahr.; and all these results are set forth in the following—

TABLE II.

Interval in Miles.	Cubic Feet in Interval.	Density per Cubic Foot. (Pounds.)	Weight / T (Pounds.)
0 to 5	1.448090×10^{20}	0.0587773	8,511,482,035,700,000,000
5 " 10	1.455762×10^{20}	0.0299611	4,361,623,085,820,000,000
10 " 50	1.177225×10^{21}	0.0047414	5,581,694,615,000,000,000
50 " 100	1.504826×10^{21}	0.00001478	22,241,328,280,000,000
100 " 200	3.123126×10^{21}	0.00000000887	27,702,127,620,000
200 " 250	1.428056×10^{21}	1.0×1330^{-15}	1,900,000
Total, $\frac{'W}{T} = D$ - - - - - - - - -			18,477,068,766,929,520,000
T = - - - - - - - - - - - - - - - - - -			0.629960
Total weight of atmosphere; W = - -			11,639,814,240,000,000,000

Weight per square inch at Earth's surface,	14.7293 pounds.
Computed normal atmospheric pressure per square inch, for sea-level, latitude 45°, temperature 32° Fahrenheit	14.7293 pounds.
Observed normal pressure,	14.7302 pounds.
Difference, in parts of normal pressure,	$\frac{1}{16,380}$ pounds.
Weight of the atmosphere including normal quantity of aqueous vapor, or water	5,819,907,120,000,000 tons.
Weight of water normally in atmosphere,	12,980,721,000,000 tons.
Weight of the atmospheric gases,	5,806,926,399,000,000 tons.
Weight of the Earth,	6,591,000,000,000,000,000,000 tons.
Relative weight of the atmosphere,	$\frac{1}{1,132,500}$

The difference between the value of the observed normal barometric pressure and the value which I have derived, as described just above, through computations based upon the principles and processes of my general hypothesis as to the constitution and functions of gases, shows that this hypothesis has enabled me to obtain a result true to—very approximately—the $\frac{1}{164}$ part of one per cent, or 1 in 16380,—a fact which, I think, adds considerably to the strength of said hypothesis.

The total weight of the atmospheric gases, set forth above, includes that of the aqueous vapor contained in the atmosphere when the normal relative humidity is 59 per cent, for a surface temperature of 32° Fahrenheit, and the proportional weight of this vapor is easily determinable, because the experiments of Regnault show that, at that percentage of humidity, one cubic foot of air, weighing 0.0804338 of a pound, contains 0.0001794 of a pound of aqueous vapor, which quantity is 0.0022304 of the whole weight of the atmosphere aforesaid; so that if the total weight be multiplied by the number last named, the result will be the normal weight—in pounds—of all the aqueous vapor, or water, contained by the atmosphere, and this weight I have thus found to be 25,961,442,000,000,000 pounds, and deducting this from the total weight of the atmosphere, as given in Table II, the weight of dry air, or purely gaseous matter, in the whole volume of the Earth's gaseous envelope is found to be 11,613,852,798,000,000,000 pounds.

From the expressions showing the relation between pressure, density and temperature, set forth on a preceding page, it is apparent that the relative pressure of the atmosphere, at each altitude up to the limiting one, is the product of the relative density and the relative temperature at each altitude, the numerical values of which quantites are set forth in Table I; the

resulting relative pressures appear in the second column of Table III following.

The normal barometric height, at sea-level in latitude 45°, and at temperature 32° Fahrenheit, is, very approximately, 30 inches, the normal barometric pressure 14.7302 pounds per square inch, and the normal absolute temperature 491°.65 Fahrenheit, and by multiplying the two first named qantities by the relative pressures in Table III, and the normal temperature above mentioned by the relative temperatures set forth in the last column of Table I, I have obtained the results which appear in the three last columns of Table III following:

TABLE III.

Altitude in Miles.	Relative Pressure.	Normal Barometric Pressure. Pounds per Square Inch.	Normal Barometric Height. Inches.	Intrinsic Absolute Temperature. Degrees Fahr.
0	1.000000	14.7302	30.0000	491.65
1	0.799574	11.7778	23.9870	449.57
2	0.639172	9.4150	19.1749	411.06
3	0.510837	7.5246	15.3248	375.81
3.1	0.500000	7.3651	15.0000	372.59
4	0.408173	6.0124	12.2450	343.56
5	0.326069	4.8030	9.7819	314.04
6	0.260422	3.8360	7.8125	287 03
7	0.207944	3.0630	6.2382	262.32
8	0.165996	2.4452	4.9800	239.71
9	0.132489	1.9516	3.9747	219.05
10	0.105720	1.5574	3.1718	200.13
20	0.010926	0.1610	0.3278	80.75
30	0.001104	0.0163	0.0331	32.27
40	0.000109	0.0016	0.0033	12.78
50	0.000011	0.0002	0.0003	5.02
60	0 0000009921	0.000014613	0.000029763	1.951
70	0.0000000914	0.000001346	0.000002742	0.752
80	0.0000000082	0.000000121	0.000000247	0.286
90	0.0000000007	0.000000010	0.000000021	0.108
100	0.0000000001	0.000000001	0.000000003	0.040
125	1.22×10^{-13}	1.79×10^{-12}	3.66×10^{-12}	0.0033540
150	2.05×10^{-16}	3.01×10^{-15}	6.15×10^{-15}	0.0002606
175	2.98×10^{-19}	4.39×10^{-18}	8.94×10^{-18}	0.0000191
200	4.16×10^{-22}	6.13×10^{-21}	1.25×10^{-20}	0.0000015
245	1.42×10^{-27}	2.10×10^{-26}	4.26×10^{-26}	0.00000001
The Ether,	1.42×10^{-27}	2.10×10^{-26}	4.26×10^{-26}	0.00000001

The temperatures which appear in the last column of Table III, and also the relative temperatures in Table I, are what may be called the "intrinsic temperatures" of the atmospheric gases at the corresponding altitudes set forth in the first column; they are the temperatures which are due simply to the mutual im-

pacts of the revolving atoms of these gases, or in other words, they are the temperatures which this gaseous matter must have so long as its ultimate particles maintain their normal orbital velocity, without regard to thermal action from extraneous sources—such as the Sun—and they are not the temperatures which would be indicated by a thermometer located at the different altitudes corresponding to the tabulated values, as the following considerations show.

The Sun, pouring its thermal radiation upon the Earth, heats the surface of our globe, and this surface, in turn, reflects a portion of the radiation which it has thus received, outward into surrounding space, and if the atmospheric air were perfectly dry the solar and terrestrial radiations aforesaid would, both, pass through it without increasing its normal intrinsic temperature, beause pure, dry air is *diathermanous*. But, as is well-known, the atmosphere is always charged, more or less, with aqueous vapor, the relative humidity, at different times and places and under differing conditions of temperature, rising above and falling below the normal value of 59 per cent, which I have adopted and used in this investigation for reasons set forth on a preceding page, and this atmospheric moisture, whether existing as invisible vapor or, in a condensed form, as clouds—but particularly in the latter case—operates to retard the thermal radiations from the Earth's surface and to retain a considerable portion of the heat thus radiated in the atmosphere below the altitude at which this vapor can be sustained in considerable quantity, the vapor thus acting as a blanket which confines the heat that would otherwise be radiated into space and lost to the Earth, and the radiation thus asserted heats the air above the normal *instrinsic* temperatures set forth in Tables I and III. Therefore a thermometer taken up in a balloon to different altitudes must usually indicate temperatures considerably higher than the normal intrinsic temperatures aforesaid, the amount of excess depending upon the location of any given place upon the surface of the Earth vertically below the position of the balloon, upon the surface temperature at said place, and, largely, upon the relative humidity and the presence of clouds in greater or less density in the air above the balloon.

For reasons stated by me in POPULAR ASTRONOMY February, 1908, it appears that the absolute temperature of the atmosphere at the Earth's surface is increased, by solar thermal radiation, to the extent of about thirty per cent of its intrinsic

value, and the volume of the atmospheric envelope is, consequently, expanded by the same percentage, the amount of the *linear* expansion being, roundly, ten per cent so that, since practically the whole sensible mass of the atmospheric gases is included within a height of fifty miles, the upper limit of the atmosphere is raised, by this linear expansion, through a distance of five miles above the limit (245 miles) unaffected by the Sun's heat, the upper limit of the atmosphere so affected being, therefore, at a height of, roundly, 250 miles above the Earth's surface or sea-level. The pressures and temperatures of the atmosphere at intervals up to a height of forty miles, which are all that need be considered in this connection, are set forth in Table IV following, these quantities being, of course, *mean* values from which there may be considerable departures, in divers cases, due to local terrestrial and cosmical causes.

The temperatures set forth are based upon a normal surface temperature of 32° Fahrenheit, or 492° absolute, at sea-level, and if the surface temperature have any value (t_o) other than 32°, the quantity (t_o-32°) must be added to the tabular values above set forth in the two last columns. It will be observed that the center of mass of the atmosphere is raised, by the expansion due to solar heat, from 3.1 miles, as given in Table III, to 3.5 miles, as indicated in Table IV.

TABLE IV.

Height Miles.	Relative Pressure.	Pressure Pound per sq. inch.	Barometer Inches.	Absolute Temperature Degrees Fahr.	Temperature Fahrenheit.
0	1.000	14.73	30.00	492	+32°
1	0.819	12.07	24.57	474	14
2	0.670	9.87	20.11	462	+ 2°
3	0.548	8.07	16.43	451	− 9°
3.5	0.500	7.37	15.00	446	14
4	0.447	6.59	13.42	441	19
5	0.365	5.37	10.95	432	28
6	0.297	4.38	8.92	424	36
7	0.242	3.57	7.26	417	43
8	0.200	2.94	6.00	410	50
9	0.170	2.50	5.10	404	56
10	0.150	2.21	4.50	400	60
20	0.036	0.53	1.08	200	260
40	0.004	0.06	0.12	20	−440°

The barometric pressures and heights tabulated just above are for a normal temperature of 32° Fahrenheit, or 492° absolute, at sea-level in latitude 45°, so that if we would determine

the altitude from an observed barometric height by means of Table IV, the altitude found from this table must be multiplied by $1 + 0.002\ (T' - 492°)$ the quantity represented by T' being the arithmetical mean of the observed absolute temperatures at the higher and lower stations, which factor is a well-known one depending upon the coefficient of expansion for gases in general; the mean of the temperatures for the different altitudes, as found from Table IV can be used instead of the *observed* values in ordinary cases, because, as will be shown subsequently, the tabulated values of the temperature differ generally but little from those observed. Furthermore, when the altitude is to be determined for any other latitude (l), the well-known factor ($1 + 0.003 \cos 2\,l$) must be introduced; so that, designating the altitude as found from Tabe IV by h, and the true altitude by H, we have the following expression—

$$H = \Big(1 + 0.002\ (T' - 492°)\Big)\ (1 + 0.003 \cos 2\,l) \cdot h, \qquad (a)$$

and the true, mean barometric height is that found from Table IV for an altitude expressed by—

$$h = \frac{H}{\Big(1 + 0.002\ (T' - 492°)\Big)\ (1 + 0.003 \cos 2\,l)}, \qquad (b)$$

H representing the altitude for which the barometric height, or pressure, is required.

The values of the pressures and heights which are set forth in Table IV are for a normal relative humidity of 59 per cent, at a surface temperature of 32° Fahrenheit, and, if the humidity is to be disregarded the tabular barometric heights must be decreased by the quantity expressed by $0.041\ p$, the value 0.041 being the tension—in inches—due to the aqueous vapor normally in the atmosphere, the effect of which has been included in the tabulated values aforesaid, while the quantity designated by p is the relative pressure found from the second column of Table IV, for any altitude within the presented limit.

Values of the barometric height for any altitude within said limit, found by means of the tabular values corrected as aforesaid, are the mean values unaffected by humidity, and if the latter is to be taken into account, the value of the barometric height taken from the table aforesaid must be increased by the quantity expressed by $(0.377\ p\ m\ e - 0.041\ p)$ in which m represents the "relative humidity" observed, and e the vapor-tension—in inches—corresponding to any observed temperature,

TABLE V.

Interval in Miles.	Weight of Atmosphere in Interval. (Pounds.)	Percentage of Weight in Each Interval.
0 to 5	7,392,678,820,000,000,000	3.5120
5 " 10	2,718,199,260,000,000,000	23.3526
10 " 50	1,527,842,017,000,000,000	13.1260
50 " 250	1,094,143,000,000,000	0.0094
Total, - -	11,639,814,240,000,000,000	100.0000

while the numerical coefficient 0.377 is due—as explained on preceding pages—to the difference of density between aqueous vapor and dry air, under equal normal conditions; therefore, if the value of the barometric height, derived from Table IV be designated by b, and the value of the height as effected by humidity by b_m, the following equation expresses the relation between these quantities.

$$b_m = b + (0.377\, pme - 0.041\, p). \qquad (c)$$

In the following table are set forth the values of e for Fahrenheit temperatures within the ordinary range of observation, e being expressed in inches:

Temperature.	e	Temperature.	e
−20°	0.0118	60°	0.5157
0	0.0445	80	1.0243
20	0.1067	100	1.9184
40	0 2468	120	3.4441

Since the effect of the decrease of the force of gravity with the altitude has been taken into account at the beginning of this work and is included in the tabulated values, all the corrections necessary to be applied so that either the barometric pressure and height, or the altitude corresponding thereto, may, in any case, be derived from the values set forth in Table IV, are at hand as above stated, and I will now demonstrate that the values of the aforesaid quantities, as found by my method, are practically identical with those derived through well established

formulæ expressive of the relation between altitude, barometric height and pressure, temperature and humidity.

The following hypsometric formula is one well-known to students of this subject—

$$h' = 18420\ (1 + 0.0036\ t')\ \ (1 + 0.003\ \cos\ 2\ l)\ (1 + 0.377\ s)$$
$$\left(1 + \frac{2\,z + h'}{6378150}\right) \cdot \log \frac{b'}{b''}, \qquad (d)$$

in which h' represents the difference of altitude (in meters) between an upper and a lower station of observation; t' the mean of the observed centigrade temperatures at said stations; l the latitude of the lower station; s the mean of the ratios between the vapor-tensions (in millimeters) corresponding to the temperatures at the stations and the respective barometric heights b' and b'' which are, also expressed in millimeters, b' representing the height at the lower station and b'' that at the upper one; while z represents the altitude of the lower station, above the normal sea-level, this altitude being expressed in meters.

Now I find that the values of either the altitude or the barometrical heights and pressures derived by means of my method aforesaid are practically in perfect agreement with those found by means of Formula *d*, which has been proved true by the results of experiment; therefore, the truth and accuracy of my determinations set forth above may be regarded as established, and I will now introduce most convincing testimony to this effect.

On September 5th, 1862, Mr. Glaisher at Wolverhampton, England, made his most famous balloon ascension, probably the most remarkable one in the annals of æronautics by reason of the great altitude which he attained therein, the highest point reached being between six and seven miles above the normal sea-level, or fully three miles above the center of mass of the atmosphere, and a point much above which man cannot, probably, exist, since Mr. Glaisher became unconscious when at an altitude of nearly six miles.

When ascending, his last recorded observation of the barometric height, as corrected, was 9.75 inches, and the thermometric observations made at the same time showed a temperature of —5° Fahrenheit, and after reducing for temperature and humidity by my formulæ set forth on a preceding page, I find from Table IV that this observed barometric height corresponds to an altitude of 5.549 miles, or 29,298 feet, while the value as determined by means of the ordinary Formula *d* is 29,244 feet, a value practically identical with mine, as the difference is

much less than the probable errors of observation would cause.

But the temperature observations made during this ascension, furnish, probably, even stronger evidence in favor of my general hypothesis, and the following table contains the results of observations taken at different altitudes (the temperatures at the Earth's surface, at time of starting, being 59° Fahrenheit) and also the computed values derived from Table IV.

ALTITUDE. (IN MILES)	1	2	3	4	5	5.549
Observed temperature..	41°	32°	18°	8°	−2°	−5°
Computed temperature	41	29	18	8	−1	−6
Difference (O − C)	0°	+3°	0°	0°	−1°	+1°

A comparison of the observed with the computed, or theoretical, values of the temperatures shows that they are, practically, in perfect agreement,—a fact which constitutes strong testimony in favor of my hypothesis from the fundamental principles of which have been deduced the mathematical formulæ through which the computed values have been determined.

Although many other ascensions have been made since the aforesaid famous one by Glaisher and his assistant Coxwell, nearly half a century ago, I think this has never been equalled by any other, either with respect to the altitude attained by thoroughly scientific observers, or the quality and detail of the observations made.

Morever, this ascent was made, practically, under perfectly normal meteorological conditions, which is a most important fact since at heights within a mile or two of the Earth's surface local conditions often cause the temperatures to differ considerably from the normal values, the variation of temperature being sometimes actually *inverted*—an increase instead of decrease of the temperature having been occasionally noted. The physical effects upon Mr. Glaisher and his assistant when at a height of nearly seven miles, indicates that this is about the limit to which human beings can ascend and remain conscious, and it is quite certain that no observer could live at a height of ten miles. Of course, balloons carrying only self-registering instruments for the measurement of altitudes, temperatures and humidity have been carried to greater heights, but the mathematical principles of Aeronautics indicate that such cannot ascend to a

height much—if any—beyond fifteen miles, while an altitude of twenty miles is, practically, unattainable by any device of man, so that the only knowledge that we can gain of the condition of the atmosphere above this limit must be derived from a theory of the atmosphere based upon observed conditions nearer the surface, and since the one that I have advanced concerning the general nature of gases, gives satisfactory results throughout, those set forth above, may be regarded as representing the normal conditions of the atmospheric envelope of our globe. The normal temperature at any height is to be derived from either of the two last columns of Table IV, either directly, or by interpolation for a normal temperature (t_0) of 32° Fahrenheit at the surface of the Earth, while for any other value of the surface temperature the correction (t_0—32°) must be added, and for considerable heights, it will suffice to take for the value of t_0 the mean temperature of the month, while for very great altitudes this correction may be neglected for most practical purposes. I have found among my notes one concerning the ascension of a balloon carrying only self-registering instruments, at Dresden, Saxony in the fall of 1907, the maximum height attained as derived from the record having been about thirteen miles at which height the temperature, as recorded, was —148° Fahrenheit. Now, by interpolating directly from the temperature column in Table IV, for that height, with the basic temperature of 492° Fahr. absolute, or 32° Fahr., the result obtained would be —130° Fahr., or only 18° less than the recorded value, while for an altitude of only one mile greater it would be —150° Fahr., or only 2° different. Since it may well be that the altitude deduced from the recorded barometric pressure may differ by approximately a mile, or the temperature may differ from the normal by the aforesaid amount, so that the above comparison between the results of observation and the computations founded upon my theory, may be regarded as verifying the latter.

Saint Paul, Minnesota.

To be continued.

THE CONSTELLATION CAMELOPARDALIS.

EDWARD C. PICKERING.

The name of the constellation Camelopardalis, is also spelled Camelopardalus and Camelopardus in astronomical works in common use. It may be of interest to learn which of these

forms is supported by the best authority. Three questions may be asked. 1. What is the best classical authority? 2. What is the usage among zoologists? 3. Which name is most commonly employed by astronomers?

Professor Morris H. Morgan has kindly answered the first of these questions as follows:—

Greek: The form is καμηλοπάρδαλις. It appears to be found first in the Alexandrine age, in the geographer Agatharcides (ap. Photium Cod. 455 b. 4, ed. Bekker). Curiously enough, on the margin of the principal MS. of Photius, there is in Greek a scholion by some unknown writer who says that he "once saw one of these creatures which had been sent to our king by the ruler in Alexandria, and the barbarian who brought the animal called it ζοράφις." Thus is preserved the original Arabic (?) name or at least an attempt at it; for our modern dictionaries refer Giraffe to Arabic *Zurāfa*. This, however, is beside your question. Besides in Agatharcides, the word καμηλοπάρδαλις is found in Diodorus Siculus (2,51); in Athenaeus (201C) and in Heliodorus (10,27). I am not aware that the word is found in any other form in Greek.

Latin: Here the oldest writers give us a transliteration of the Greek just mentioned, and write *camelopardalis*; see Varro (L.L. 5,100), Pliny (N.H. 8, 69). In a writer of the third century after Christ, we find *camelopardalus*, i.e., in Capitolinus (Gord. III, 33); also in a fourth century writer, Vopiscus (Aur. 33); and the same form is in our printed editions of the Vulgate (Deut. 14,5). Finally, the form *camelopardus* occurs in the sixth century writer Isodorus (Orig. 12, 2, 19).

In view of this, if you want to call your constellation by the classical form of the name, both Greek and Latin demand *camelopardalis*. And this form is further vouched for by the classical Greek form of the word for 'panther'. It is πάρδαλις from Homer to Aristotle (see Liddell and Scott's Lexicon for the passages). The form πάρδος occurs in Aelian, second to third century after Christ (N.A. 1, 31; though one MS. gives πάρδαλος here, but it is not accepted by editors). In Latin, however, *pardus* is found three times in Pliny (N.H. 8, 63; 10,202; 11,172); also in Juvenal (11,123); and in the Vulgate (Jer. 13,23). The form *pardalis* occurs only in Curtius (5,1,22) who was a contemporary of Pliny. But *pardalus* does not seem to occur anywhere in Latin.

I have used the word 'panther,' but it should be noted that the Greek and Latin words which I have just been citing should

not be too strictly confined to that species of animal; for I believe that the ancients did not always distinguish between panther, leopard, ounce, etc. etc., but used *pardus* and *pardalis* of any catlike animal with spots. To conclude, *camelopardalis* was the earliest Greek and Latin word for 'giraffe.'

Mr. Alexander Agassiz has courteously given the following answer to the second question:—

Camelopardalus, Jonst. is a pre-Linnean (1755) name, hence not in use. Camelopardalis, Gmelin, dates back to 1788. Linnè called the Giraffe, Cervus Camelopardalis, 1780. Gmelin called it Camelopardalis Giraffa, 1788. The name Giraffa dates from Storr, 1780, who called the Giraffe, Giraffa Camelopardalis, and finally Brehm called it Camelopardalis Giraffa, in 1877. I do not find the name of Camelopardus. So that the present name of the Giraffe is Giraffa Camelopardalis. I get this from Scudder's Genera in Zoology.

In answer to the third question:—

This constellation was formed by Bartsch, and the name Camelopardalus was given to it by Hevelius, Prodromus Astronomiae, 1690, both in the Catalogue and on the Maps.

The spelling Camelopardalus also appears in the following works:—

Flamsteed. 1725. Johannis Hevelii Catalogus Stellarum Fixarum, 1660, p. 68.

Flamsteed. 1725. Catalogus Britannicus, 1689, p. 40.

Herschel, W. Fourth Catalogue of the Brightness of the Stars. Phil. Trans. 1799, p. 138.

Herschel, J. and South. Distances and positions of 380 Double and Triple Stars. Phil. Trans. 1825, p. 67.

Argelander. Uranometria Nova, 1843, p. 4, and Map I.

Index. Astron. Nach. 1875, **61-80**, p. 70.

Index. Astron. Nach. 1891, **81-120**, p. 386.

The spelling Camelopardalis occurs in the following works:—

Herschel, W. 145 New Double Stars. Mem. of the Astron. Soc. 1821, **1**, p. 10.

Heis. Atlas Coelestis Novus, 1872, p. 23, and Pl. I.

Astron. Nach. 1866. Index, **41-60**, p. 9.

Astron. Nach. 1902. Index, **121-150**, p. 383.

Vierteljahrsschrift der Astron. Gesell., 1908, **43**, p. 145.

Chandler. Third Catalogue of Variable Stars, Astron. Journ. 1896, **16**, p. 145.

Amer. Ephem. and Naut. Almanac, 1911, p. 305.

Encyc. Britannica, 1875, **2**, p. 817.

Century Dictionary, 1889, **1**, p. 777.

The spelling Camelopardus occurs in the following works:—

Bailey. The British Catalogue of Stars, 1835, p. 383.
Bailey. The Catalogue of Stars of the British Assoc., 1845, p. 64.
Smyth. A Cycle of Celestial Objects. 1844, **1**, p. 409.
Webb Celestial Objects for Common Telescopes; 1859, p. 175.
Schönfeld. Zweiter Cat. für Veränr. Sternen, 1875, p. 16.
Chandler. Catalogue of Variable Stars. Astron. Journ. 1888, **8**, p. 86.

It, therefore, appears that the correct spelling, according to the best classical authorities both Greek and Latin, is Camelopardalis, which is that adopted by the zoologists, and is that commonly used in later standard works on Astronomy. The name given to the constellation by Hevelius, and followed by Flamsteed, W. Herschel, and other older astronomers, was Camelopardalus. The spelling Camelopardus was adopted by Bailey, Schönfeld, and others.

Harvard College Observatory,
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A YEAR AMONG AMERICAN ASTRONOMERS.*

H. C. PLUMMER.

The fascinating interest which the Lick Observatory possesses for all astronomers is undeniable and easily understood. The great telescope, though in the mere matter of size it retained its supremacy for scarcely a decade, is still unsurpassed in quality and effective power. At the time when it was projected, it had not become, as it has become later, a common practice in establishing observatories to allow exclusive consideration to the astronomical efficiency of the site. It is curious to reflect that at one time Mr. Lick had intended to locate his observatory in Market Street, San Francisco. Happily, wiser counsels prevailed, and Mount Hamilton, 4000 feet high and 50 miles south of San Francisco, was chosen. How much the history of astronomy during the last twenty years owes to the energy and the ability of the workers on Mount Hamilton is known to all. It was very natural, therefore, that when the offer of a fellowship made it possible for me to spend a year there, I readily embraced the opportunity. For the offer I am deeply indebted to the liberal policy of the University of California, and to the good offices of Prof. Turner, who also obtained for me a year's leave of absence and a very generous grant from the Board of Visitors of the University Observatory at Oxford.

* *The Observatory*, January, 1909.

In the latter half of August 1907, I sailed to Halifax, N.S., and proceeded with as little delay as possible across Canada to Vancouver. It has since been a matter of regret that time did not permit of a visit to the Dominion Observatory at Ottawa, where, under the direction of Dr. King, Mr. Plaskett, assisted by Mr. Harper, has been doing excellent work in astrophysics, and has lately installed modern apparatus for the study of solar physics. The journey across Canada was uneventful, except in so far as the day spent in crossing the Rockies and the Selkirks may be considered in itself an event. The voyage from Vancouver to Victoria and Seattle on a perfect day was also full of beauty, but perhaps the most impressive sight on the outward journey was the view of Mount Shasta from the train as night was falling and the snow-clad summit stood out rose-pink against a sky of deepest blue. The next morning I was in San Francisco, which at that time still impressed the traveller with the full extent of the disaster which had overwhelmed it some eighteen months before. With no reason to tarry, I went on immediately to San José, and thence on the following day, September 12, the stage which makes its daily journey over the twenty-eight miles of excellently graded road to the top of Mt. Hamilton took me to the famous Lick Observatory. A warm welcome was extended to me at once, and I can never be sufficiently grateful for the unfailing kindness which, from that day on, I received from my American colleagues and their families.

One may take it for granted that there has never been a time when the members of that community on the top of Mount Hamilton have not been fully occupied. In spite of the isolation time does not hang heavy on their hands. But at the time of my arrival, and during the two months following, the activity was exceptional. At the end of November, the Crocker eclipse expedition was to start to Flint Island. It is safe to say that the Lick Observatory eclipse expeditions are models of organization in this line of work; the volume of Lick Publications in which the detailed discussion of the results will ultimately appear will be a truly notable contribution to the subject. On other occasions parties have been sent from this Observatory to occupy two or three different points on the line of totality. In this case all the energy was to be concentrated on one small island, and, except for the enterprising venture of Mr. McClean, there would be no other party to share the responsibility. No more complete arrangements have ever been made by a single observatory. Old instruments which had seen service in previ-

ous campaigns had to be examined and adjusted; there were clocks to be rated; new instruments were designed and manufactured on the spot. Of one of Dr. Campbell's specially designed instruments some description may be given here, partly because it does not seem to be very well known in England, and partly because I was engaged for some weeks this summer in measuring and reducing a fine plate obtained by Dr. Campbell with similar apparatus at the Spanish eclipse of 1905.

Most people are familiar with the ordinary prismatic camera, which consists of an objective prism-train in front of a lens. The solar crescent immediately before second contact, or immediately after the third contact, is, in effect, a curved slit at infinity. The camera forms a series of monochromatic images corresponding to the prominent lines in the chromospheric spectrum. By placing in front of the plate a narrow slit, only the central portion of these crescent images is allowed to impress itself on the plate. Consequently, if the plate is caused to move in the direction perpendicular to the slit, straight images will be obtained instead of curved. A very uniform motion is communicated to the plate-holder by connecting it with a piston which is made to force water through a valve under constant pressure. The beauty of the arrangement will now be clear. Let us suppose, for example, that the plate-holder is released just before third contact. The spectrum first formed must be due to the outermost stratum of the chromosphere. As the Moon moves off, lower and lower strata are uncovered and become effective. But meanwhile the plate is in corresponding motion, and therefore it will bear the record of the chromospheric spectrum from the outer surface down to the photosphere. The new "moving-plate spectrograph" was designed with three prisms instead of two, as in the case of the instrument employed by Dr. Campbell in Spain. In order that a large range of spectrum should be in focus with this increased dispersion it was necessary to give the plate a considerable curvature; glass plates refused to stand the strain, and accordingly stiff films were ordered and used instead.

It will be easily understood that with an instrument of this kind success depends on the most careful and accurate adjustment. The spectrum obtained by Dr. Campbell at third contact in Spain showed perfect focus over a large range, and the plate will well repay the most exhaustive study, for it conveys a wonderful amount of information. The strongest lines which appear at the highest level are naturally those due to calcium

and hydrogen, but it was surprising to find that the element which gave rise to the next strongest line was strontium. In fact there were several of the heavier elements which appeared side by side with hydrogen and helium in the upper layer of the chromosphere, and it seems possible that the results would have been still more interesting if the plate had been released and the exposure begun at an earlier moment. There is much variety in the character of the lines. Not only is it possible to determine the relative height at which the lines become strong enough to impress the plate, but also in many cases the change from bright line to absorption line is abrupt and well marked, though in others the bright line becomes merged in a layer of continuous spectrum. Below this layer it is only the strongest absorption lines which can be seen. The gradual widening of the crescent as the eclipse proceeds impairs the purity, and the the gradual increase of light cannot fail to produce over-exposure unless provision is made for accelerating the motion of the plate-holder. I measured more than 1300 lines on Dr. Campbell's Spanish plate, and identified the majority with lines in Rowland's table. The results will appear in the forthcoming eclipse volume of the Lick Publications. Dr. Campbell obtained another well-deserved success with his re-modelled apparatus on Flint Island.

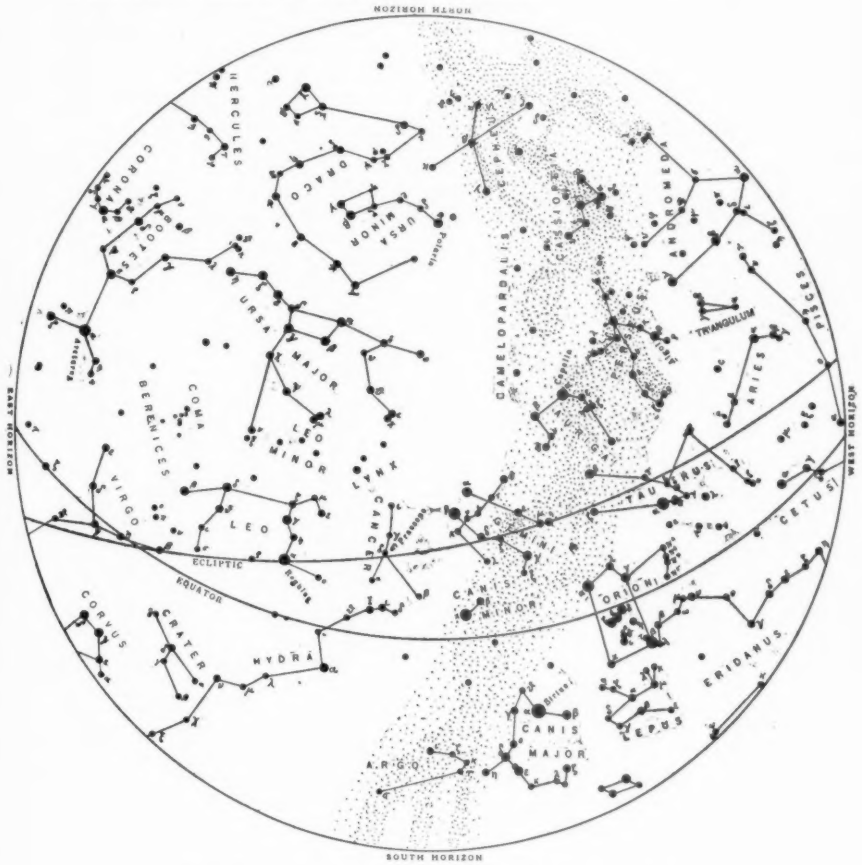
GIFT TO CAMBRIDGE OBSERVATORY.—In the year 1871 the Royal Society provided certain instruments for the use of Sir William Huggins in his astrophysical researches, but as Sir William now finds it necessary to discontinue active astronomical observations in order to devote himself to cognate physical researches, these instruments revert by his desire to the Royal Society, and that body has offered them unreservedly to the Cambridge Observatory.

The instruments consist of (1) a refracting telescope (with an object glass 15 inches in diameter and 15 feet in focal length) to which is attached a spectroscope arranged for both visual and photographic work, and (2) a Cassegrain reflecting telescope (with a mirror made of speculum metal, 18 inches in diameter and about 7 feet in focal length) to which a spectroscope is attached with optical parts made of Iceland spar and quartz, for photographing the ultra-violet spectrum of stars. These two telescopes are mounted equatorially on a single polar axis in such a way that they can be moved independently in declination.

The observatory syndicate has accepted this valuable gift, and a sum of money has been provided as part of the expenses of removing and installing the instruments.—*The Observatory*, No. 405.

PLANET NOTES FOR MARCH, 1909.

Mercury will be at greatest elongation, west from the Sun 27° 26′ on March 9, and will be visible as morning star for a few days at that time. This planet will not be by any means so conspicuous as Venus, which will be visible toward the E. S. E. at the same time. Mercury will on the morning of March 9 be about 15° around toward the south from Venus.



THE CONSTELLATIONS AT 9:00 P. M., MARCH 1, 1909.

Venus will continue to be morning star through March, but is getting so near to the Sun as to be seen for only a short time and in the bright dawn.

During the past month, many people have noticed Venus as a brilliant star toward the southeast between six and seven o'clock in the morning. Some

newspaper reporter has started the old story of the re-appearance of the "Star of Bethlehem" going the rounds again and several people have jumped to the conclusion that Venus was that star. Venus is simply going through her regular phases and is less brilliant now than she was a few months ago. She will pass behind the Sun in April and after that become evening star.

Mars is near the meridian at a low altitude at half past seven o'clock in the morning, and so may be observed best just before dawn.

Jupiter is at opposition on the last day of February, and may now be studied during the greater part of the night. The belts of Jupiter and the four bright satellites may be seen with the aid of quite a small telescope. Jupiter is the brightest object in the eastern sky in the early evening except when the Moon is in that vicinity.

Saturn is still visible toward the west in the early evening, but is too far down toward the Sun for satisfactory study.

Uranus is to be found in the morning in the constellation Sagittarius. This planet, which requires the use of a good telescope, may be found near Mars on the mornings of March 26 and 27. The two planets will be in conjunction March 26 at 3 P. M. Central Standard time, Uranus being then 18′ north of Mars.

Neptune will be stationary at the west end of its path for this year, in the constellation Gemini on March 25.

Occultations visible at Washington.

Date 1909	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle from N. °	EMERSION. Washington M.T. h m	EMERSION. Angle from N °	Duration. h m
Mar. 1	48 Geminorum	5.8	7 30	90	9 03	274	1 33
5	46 Leonis	5.8	6 00	70	6 50	319	0 50
12	β^2 Scorpii	2.9	16 19	76	17 29	332	1 10
12	56 B Scorpii	5.0	16 20	74	17 28	334	1 08
14	63 Ophiuchi	6.1	15 59	118	17 17	270	1 18
28	ω Geminorum	5.2	11 02	101	12 05	280	1 03
30	γ Cancri	4.9	7 37	183	7 58	209	0 21

COMET NOTES.

Search Ephemeris for Halley's Comet.—In *A.N.* 4295 Mr. A. F. Lindemann gives search ephemerides for Halley's comet extending from Dec. 28, 1908 to Dec. 28, 1910. He does not tell what elements were employed in computing the ephemerides, but the time of nearest approach to the Earth is evidently about June 29. If this should be right, it would put the comet in very nearly the same position as in 1456 when it was a magnificent object in the heavens.

The following is the portion of the ephemerides for the year 1909:

Date 1909	α h	m	δ °	′	Aber.-time m	Date 1909	α h	m	δ °	′	Aber.-time m
Jan. 7	5	57.1	+11	19	45.0	Feb. 6	5	34.2	+12	00	45.4
17		48.8	11	31	44.9	16		28.5	12	18	45.9
27		41.0	11	44	45.1	26		24.1	12	38	46.6

Date 1909	α h	α m	δ °	δ ′	Aber.-time m
Mar. 8	5	21.0	+12	59	47.3
18		19.2	13	21	48.1
28		18.6	13	42	48.8
Apr. 7		19.1	14	04	49.4
17		20.7	14	25	50.0
27		23.2	14	45	50.3
May 7		26.5	15	03	50.5
17		30.4	15	20	50.5
27		34.8	15	35	50.3
June 6		39.6	15	48	49.9
16		44.8	15	59	49.3
26		50.3	16	08	48.5
July 6		55.7	16	14	47.6
16		01.2	16	18	46.1
26	6	06.5	+16	19	44.6

Date 1909	α h	α m	δ °	δ ′	Aber.-time m
Aug. 5	6	11.5	+16	18	43.0
15		16.1	16	15	41.1
25		20.0	16	10	39.1
Sept. 4		23.1	16	04	37.0
14		25.2	15	56	34.7
24		25.7	15	48	32.4
Oct. 4		24.5	15	38	30.0
14		21.0	15	29	27.6
24		14.6	15	20	25.3
Nov. 3	6	04.9	15	11	23.2
13	5	51.1	15	01	21.2
23		33.0	14	50	19.5
Dec. 3	5	10.5	14	35	18.1
13	4	44.5	14	15	17.2
23	4	16.9	+13	49	16.6

Ephemeris of Comet 1908 *c* (Morehouse).

From *A.N.* 4296.

1909	α h	α m	α s	δ °	δ ′	log *r*	log Δ	H
Mar. 1	18	29	47	−58	57.6	0.1636	0.1598	2.92
2		27	47	59	53.2			
3		25	34	60	49.7			
4		23	7	61	47.2			
5		20	23	62	45.6	0.1777	·01455	2.92
6		17	21	63	44.9			
7		13	57	64	44.9			
8		10	10	65	45.7			
9		5	55	66	47.0	0.1915	0.1321	2.91
10	18	1	8	67	48.8			
11	17	55	43	68	50.8			
12		49	35	69	53.1			
13	17	42	35	70	55.3	0.2050	0.1204	2.88
14		34	36	71	57.3			
15		25	26	72	58.5			
16		14	55	73	58.7			
17	17	2	45	74	57.0	0.2182	0.1108	2.84
18	16	48	41	75	53.1			
19		32	24	76	45.8			
20	16	13	38	77	34.2			
21	15	52	6	78	17.1	0.2311	0.1041	2.76
22		27	45	78	53.0			
23	15	0	40	79	20.5			
24	14	31	23	79	38.1			
25	14	0	43	79	44.7	0.2436	0.1009	2.65
26	13	29	50	79	39.8			
27	12	59	53	79	23.5			
28		31	52	78	56.5			
29	12	6	24	78	20.2	0.2558	0.1016	2.49
30	11	43	46	77	35.8			
31		23	57	76	44.8			
Apr. 1	11	6	45	75	48.5			
2	10	51	52	74	48.1	0.2677	0.1063	2.31
3		39	1	73	44.4			
4		27	56	72	38.2			
5		18	19	71	30 3			
6		9	57	70	20.9	0.2793	0.1150	2.10
7	10	2	40	69	10.8			
8	9	56	18	−68	0.2			

1909		α			δ		log *r*	log Δ	H
		h	m	s	°	′			
Apr.	9	9	50	42	−66	49.5			
	10		45	46	65	38.9	0.2906	0.1273	1.89
	11		41	25	64	28.5			
	12		37	35	63	18.5			
	13		34	11	62	9.2			
	14		31	9	61	0.7	0.3015	0.1428	1.67
	15		28	27	59	53.0			
	16		26	3	58	46.2			
	17		23	55	57	40.5			
	18	9	22	0	−56	36.0	0.3122	0.1609	1.46

M. EBELL.

VARIABLE STARS.

Variable Star 26.1900 Vulpeculæ.—In *A.N.* 4295 Mr. T. H. Astbury gives three recent minima of this variable, two of them in September last being only five days apart. From these and four earlier observations by Flint he determines a probable period of 5.0502 days, but says that it may be half of this or $2^d.5251$. The following are the minima noted:

	Observed Minima			Observer	Computed	O − C
1	1898 Oct. 5.3	= J.D.	2414568.3	Flint	2414568.30	0.00
2	1899 Sept. 26.3	=	4924.3	"	4924.33	−0.03
3	1900 May 2.7	=	5142.7	"	5141.48	+1.22
4	Sept. 12.3	=	5275.3	"	5275.31	−0.01
5	1908 Sept. 14.39	=	8199.39	Astbury	8199.31	+0.02
6	Sept. 19.33	=	8204.33	"	8204.42	−0.09
7	Dec. 9.25	=	8285.25	"	8285.22	+0.03

The residual for the third observation may possibly indicate that the period is one fourth of five days or $1^d.26255$.

The variability of this star was announced by A. S. Flint in 1900. Its normal brightness is about magnitude 7.5, but at minimum it is below 8.5. The star is B.D. +24°.3803 and its position for 1900.0 is

$$\alpha = 19^h\ 17^m\ 31^s.66 : \delta = +25°\ 23'\ 07''.4.$$

It is probably of the Algol type.

Period and Light Curve of 122.1906 Ceti.—In *A.N.* 4290 Mr. Naozo Ichinohe of the Tokio Observatory gives a long series of observations of this variable star, B.D. +0° 249 $1^h\ 24^m\ 39^s$ + 0° 35′.3 1855, the variability of which was announced first by Egon R. v. Oppolzer in 1906. Mr. Ichinohe finds the star to be intermediate between the cluster and δ Cephei types, with a period of 0.55302 day. The elements are

$$\text{Maximum} = 2417495^d.380 + 0^d.55302\ E.$$

From the minimum to the maximum it takes only two hours, and there is no stop at the maximum. The decrease is quite slow, and it takes 7.2 hours from the maximum to the minimum. In the remaining five hours, the brightness is practically constant at minimum.

New Variable 173.1908 Aurigæ.—In *A.N.* 4286 Mr. M. Luizet announces the variability of the 9.5 magnitude star B.D. +48°.1189. Its place for 1900.0 is

$$\alpha = 4^h\ 51^m\ 26^s.0;\ \delta = +48°\ 08'.6.$$

On April 30 last, it was invisible or at least could not be distinguished among

its faint neighbors. The same was true on Sept. 18 and 19; but on Oct. 31, it was again at about magnitude 10, while on Nov. 5, it was as bright B.D. +48° 1183 which is rated at 9.5, and on Nov. 12 it appeared a little brighter. It is probably a long period variable.

New Elements of the Variable RV Ursæ Majoris.—In *A.N.* 4292 Mr. M. Luizet of Lyons, France, gives new elements and a light curve of the variable RV Ursæ majoris, depending upon observations of ten maxima in the year 1908. The new elements are

Maximum = 2417854.411 (Paris m.t.) +0^d.468116 E.

The variation is of the type of δ Cephei, the maximum being short, the decrease of light occupying 7^h 26^m and the increase 3^h 48^m. The range is between the magnitudes 9.½ and 10.3.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours.]

SX Cassiop.		RZ Cassiop.		Algol		RT Persei		RV Persei	
d	h	d	h	d	h	d	h	d	h
Mar. 19	20	Mar. 7	19	Mar. 16	0	Mar. 27	9	Mar. 20	19
U Cephei		8	23	18	21	28	6	22	18
Mar. 1	21	10	4	21	18	29	2	24	18
4	9	15	1	24	14	29	22	26	17
6	21	16	5	27	11	30	19	28	16
9	9	17	10	30	8	31	15	30	16
11	20	18	15	RT Persei		λ Tauri		RW Persei	
14	8	19	19	Mar. 1	1	Mar. 2	3	Mar. 2	6
16	20	21	0	1	22	6	2	15	11
19	8	22	5	2	18	10	1	28	15
21	20	23	10	3	14	13	23	RS Cephei	
24	8	24	14	4	11	17	22	Mar. 4	1
26	20	25	19	5	7	21	21	16	12
29	7	27	0	6	4	25	20	28	22
31	19	28	4	7	0	29	19	RY Aurigæ	
Z Persei		29	9	7	20	RW Tauri		Mar. 1	9
Mar. 3	7	30	14	8	17	Mar. 3	16	4	2
6	8	RX Cephei		9	13	6	10	6	20
9	9	Mar. 17	17	10	10	9	5	9	13
12	11	ST Persei		11	6	11	23	12	7
15	12	Mar. 2	10	12	2	14	18	15	0
18	14	5	2	12	23	17	12	17	18
21	15	7	17	13	19	20	6	20	11
24	16	10	9	14	15	23	1	23	5
27	18	13	1	15	12	25	19	25	22
30	19	15	16	16	8	28	14	28	16
RY Persei		18	8	17	5	31	8	31	9
Mar. 1	18	20	23	18	1	RV Persei		RZ Aurigæ	
8	15	23	15	18	21	Mar. 1	1	Mar. 3	4
15	11	26	6	19	18	2	1	6	4
22	8	28	22	20	14	4	0	9	5
29	5	31	13	21	11	6	23	12	5
RZ Cassiop.		Algol		22	7	8	23	15	6
Mar. 1	19	Mar. 1	16	23	3	10	22	16	2
3	0	4	13	24	0	12	21	18	6
4	5	7	9	24	20	14	21	21	6
5	9	10	6	25	16	16	20	24	7
6	14	13	3	26	13	18	20		

Minima of Variable Stars of the Algol Type.—Continued.

RZ Aurigae

	d	h
Mar.	27	7
	30	7

RW Geminorum

Mar.	2	14
	5	11
	8	7
	11	4
	14	1
	16	22
	19	18
	22	15
	25	12
	28	9
	31	6

U Columbæ

Mar.	1	0
	3	19
	6	15
	9	10
	12	5
	15	0
	17	19
	20	15
	23	10
	26	5
	29	0
	31	19

RW Monoc.

Mar.	1	3
	3	1
	4	22
	6	20
	8	18
	10	16
	12	14
	14	11
	16	9
	18	7
	20	5
	22	2
	24	0
	25	22
	27	20
	29	17
	31	15

RX Geminorum

Mar.	6	22
	19	3
	31	8

RU Monoc.

Mar.	1	7
	2	5
	3	2
	4	0
	4	21
	5	19
	6	16
	7	14
	8	11
	9	9

RU Monoc.

Mar.	10	6
	11	4
	12	1
	13	20
	14	18
	15	15
	16	13
	17	10
	18	8
	19	6
	20	3
	21	1
	21	22
	22	20
	23	17
	24	15
	25	12
	26	10
	27	7
	28	5
	29	2
	30	0
	30	21
	31	19

RY Geminorum

Mar.	2	18
	12	1
	21	8
	30	15

R Canis Maj.

Mar.	1	5
	2	8
	3	11
	4	15
	5	18
	6	21
	8	1
	9	4
	10	7
	11	10
	12	14
	13	17
	14	20
	15	23
	17	3
	18	6
	19	9
	20	12
	21	16
	22	19
	23	22
	25	1
	26	5
	27	8
	28	11
	29	15
	30	18
	31	21

Y Camelop.

Mar.	3	1
	6	8
	9	15
	12	23
	16	6
	19	13
	22	21
	26	4
	29	11

RR Puppis

Mar.	5	19
	12	5
	18	15
	25	2
	31	12

V Puppis

Mar.	1	23
	3	10
	4	21
	6	8
	7	19
	9	6
	10	17
	12	3
	13	14
	15	1
	16	12
	17	23
	19	10
	20	21
	22	8
	23	19
	26	16
	28	3
	29	14
	31	1

X Carinæ

Mar.	1	13
	2	15
	3	17
	4	19
	5	21
	6	23
	8	1
	9	3
	10	5
	11	7
	12	9
	13	11
	14	13
	15	15
	16	17
	17	19
	18	21
	19	23
	21	1
	22	3
	23	5
	24	7
	25	9

X Carinae

Mar.	26	11
	27	13
	28	15
	29	17
	30	19
	31	21

S Cancri

Mar.	10	9
	19	21
	29	8

S Velorum

Mar.	1	17
	7	15
	13	13
	19	12
	25	10
	31	9

RR Velorum

Mar.	2	16
	4	12
	6	9
	8	5
	10	2
	11	22
	13	19
	15	15
	17	12
	19	8
	21	5
	23	1
	24	22
	26	18
	28	15
	30	11

SS Carinæ

Mar.	2	19
	6	3
	9	10
	12	17
	16	0
	19	7
	22	15
	25	22
	29	5

RW Urs. Maj.

Mar.	5	20
	13	4
	20	12
	27	20

Z Draconis

Mar.	1	6
	3	15
	5	0
	6	8
	7	17
	9	1
	10	10
	11	18
	13	3
	14	12

Z Draconis

Mar.	15	20
	17	5
	18	13
	19	22
	21	6
	22	15
	24	0
	25	8
	26	17
	27	22
	28	1
	29	10
	30	18

SS Centauri

Mar.	2	11
	4	23
	7	10
	9	22
	12	9
	14	21
	17	8
	19	20
	22	7
	24	19
	27	6
	29	18

δ Libræ

Mar.	1	13
	3	21
	6	5
	8	13
	10	20
	13	4
	15	12
	17	20
	20	4
	22	12
	24	20
	27	3
	29	11

U Coronæ

Mar.	1	2
	4	13
	8	0
	11	11
	14	21
	18	8
	21	19
	25	6
	28	17

R Aræ

Mar.	4	16
	9	3
	13	13
	17	23
	22	9
	26	19
	31	6

Minima of Variable Stars of the Algol Type.—Continued.

U Ophiuchi

	d	h
Mar.	1	7
	2	3
	2	23
	3	19
	4	15
	5	11
	6	7
	7	4
	8	0
	8	20
	9	16
	10	12
	11	8
	12	4
	13	0
	13	21
	14	17
	15	13
	16	9
	17	5
	18	1
	18	21
	19	17
	20	14
	21	10
	22	6
	23	2
	23	22
	24	18
	25	14
	26	10
	27	7
	28	3
	28	23
	29	19
	30	15
	31	11

Z Herculis

	d	h
Mar.	2	19
	4	16
	6	18
	8	15
	10	18
	12	15
	14	18
	16	15
	18	18
	20	15
	22	18
	24	15
	26	17
	28	14
	30	17

RS Sagittarii

	d	h
Mar.	2	20
	5	6
	7	16
	10	2
	12	12
	14	22

RS Sagittarii

	d	h
Mar.	17	8
	19	18
	22	4
	24	14
	26	23
	29	9
	31	19

V Serpentis

	d	h
Mar.	1	0
	4	11
	7	22
	11	9
	14	20
	18	7
	21	17
	25	4
	28	15

Y Leonis

	d	h
Mar.	2	2
	3	18
	5	11
	7	3
	8	20
	10	12
	12	5
	13	21
	15	14
	17	6
	18	23
	20	15
	22	7
	24	0
	25	16
	27	9
	29	1
	30	18

115.1908 Ophi.

	d	h
Mar.	3	8
	5	18
	8	5
	10	16
	13	3
	15	13
	18	0
	20	11
	22	22
	25	8
	27	19
	30	6

116.1908 Ophi.

	d	h
Mar.	2	9
	4	11
	6	12
	8	14
	10	15
	12	17
	14	18
	16	20
	18	21
	20	23

116.1908 Ophi.

	d	h
Mar.	23	0
	25	2
	27	3
	29	5
	31	6

RZ Draconis

	d	h
Mar.	1	8
	2	11
	3	13
	4	16
	5	18
	6	21
	7	23
	9	2
	10	4
	11	6
	12	9
	13	11
	14	14
	15	16
	16	19
	17	21
	19	0
	20	2
	21	4
	22	7
	23	9
	24	12
	25	14
	26	17
	27	19
	28	22
	30	0
	31	2

RX Herculis

	d	h
Mar.	1	8
	2	6
	3	3
	4	0
	4	22
	5	19
	6	16
	7	14
	8	11
	9	8
	10	6
	11	3
	12	0
	12	22
	13	19
	14	16
	15	14
	16	11
	17	8
	18	6
	19	3
	20	1
	20	22
	21	19
	22	17

RX Herculis

	d	h
Mar.	23	14
	24	11
	25	9
	26	6
	27	3
	28	1
	28	22
	29	19
	30	17
	31	14

SX Sagittarii

	d	h
Mar.	1	21
	3	23
	6	1
	8	3
	10	5
	12	7
	14	9
	16	10
	18	12
	20	14
	22	16
	24	18
	26	20
	28	21
	30	23

RR Draconis

	d	h
Mar.	2	15
	5	11
	8	7
	11	3
	16	18
	19	14
	22	10
	25	6
	28	2
	30	22

U Scuti

	d	h
Mar.	1	14
	2	13
	3	12
	4	10
	5	9
	6	8
	7	7
	8	6
	9	5
	10	4
	11	3
	12	2
	13	1
	14	0
	14	22
	15	22
	16	20
	17	19
	18	18
	19	17
	20	16
	21	15

U Scuti

	d	h
Mar.	22	14
	23	13
	24	12
	25	11
	26	10
	27	9
	28	7
	29	6
	30	5
	31	4

RX Draconis

	d	h
Mar.	1	13
	3	20
	5	18
	7	15
	9	13
	11	10
	13	8
	15	5
	17	3
	19	0
	20	22
	22	19
	24	16
	26	14
	28	11
	30	9

RV Lyræ

	d	h
Mar.	2	6
	5	20
	9	11
	13	1
	16	15
	20	6
	23	20
	27	11
	31	1

U Sagittae

	d	h
Mar.	1	17
	4	26
	8	11
	11	21
	15	6
	18	15
	22	0
	25	9
	28	18

SY Cygni

	d	h
Mar.	2	15
	8	15
	14	15
	20	15
	26	16

WW Cygni

	d	h
Mar.	2	3
	5	10
	8	18
	12	2
	15	9
	18	17

WW Cygni			VW Cygni			W Delphini			VV Cygni			VV Cygni		
	d	h		d	h		d	h		d	h		d	h
Mar.	22	0	Mar.	14	9	Mar.	4	23	Mar.	2	1	Mar.	22	17
	25	8		22	19		9	18		3	12		24	4
	28	16		31	6		14	14		4	23		25	16
	31	23					19	9		6	11		27	3
SW Cygni							24	4		7	22		28	15
Mar.	1	15	UW Cygni				29	0		9	10		30	2
	6	5	Mar.	2	11	RR Delphini				10	21		31	14
	10	19		5	22	Mar.	1	9		12	9			
	15	9		9	9		5	23		13	20			
	19	22		12	20		10	14		15	8			
	24	12		16	6		15	4		16	19			
	29	2		19	17		19	18		18	6			
				23	4		24	9		19	18			
VW Cygni				26	15		28	23		21	5	UZ Cygni		
Mar.	5	23		30	2							Mar.	7	5

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SY Cassiop.			ζ Geminorum			T Crucis			RZ Centauri			R Triang. Austr.		
	d	h		d	h		d	h		h	d		d	h
Mar.	1	10		(−5	0)		(−2	2)	Mar.	15	18	Mar.	21	8
	5	12	Mar.	1	16	Mar.	1	12		16	17		24	17
	9	14		11	19		8	5		17	15		28	3
	13	15		21	23		14	23		18	14		31	12
	17	17	RU Cassiop.				21	16		19	12	S Triang. Austr.		
	21	19		(−9	12)		28	10		20	11		(−2	2)
	25	21	Mar.	11	4	R Crucis				21	9	Mar.	2	8
	29	22					(−1	10)		22	8		8	16
RW Cassiop.			V Carinæ			Mar.	4	20		23	6		14	23
	(−5	19)		(−2	4)		10	16		24	5		21	7
Mar.	13	17	Mar.	1	15		16	12		25	3		27	15
	28	12		8	8		22	8		26	2			
				15	1		28	4		27	0	S Normæ		
RX Aurigæ				21	17	S Crucis				27	23		(−4	10)
	(−4	0)		28	10		(−1	12)		28	21	Mar.	8	13
Mar.	7	16	T Velorum			Mar.	4	19		29	20		18	7
	19	7		(−1	10)		9	12		30	18		28	1
	30	22	Mar.	1	15		14	5		31	17			
Y Aurigæ				6	7		18	21				RV Scorpii		
	(−0	18)		10	22		23	14	W Virginis				(−1	10)
Mar.	2	22		15	13		28	6		(−8	5)	Mar.	6	9
	6	19		20	5	RZ Centauri			Mar.	7	4		12	10
	10	15		24	20	Mar.	1	17		24	10		18	12
	14	12		29	11		2	15	V Centauri				24	13
	18	8	W Carinæ				3	14		(−1	11)		30	15
	22	5		(−1	0)		4	12	Mar.	5	8			
	26	2	Mar.	3	18		5	11		10	20	RV Ophiuchi Minimum.		
	29	22		8	3		6	9		16	8			
				12	12		7	8		21	19	Mar.	1	5
T Monoc.				16	21		8	7		27	7		4	22
	(−9	23)		21	6		9	5	R Triang. Austr.				8	14
Mar.	19	14		25	14		10	3		(−1	0)		12	7
W Geminorum				29	23		11	2	Mar.	4	9		15	23
	(−2	2)	S Muscæ				12	0		7	19		19	16
Mar.	6	4		(−3	11)		12	23		11	4		23	8
	14	2	Mar.	4	12		13	21		14	13		27	1
	22	0		14	4		14	20		17	23		30	17
	29	22		23	20									

Maxima of Variable Stars of Short Period not of the Algol Type

Continued.

X Sagittarii

	h	d
	(−2	22)
Mar.	5	14
	12	14
	19	14
	26	15

Y Ophiuchi

	(−6	5)
Mar.	1	11
	18	14

W Sagittarii

	(−3	0)
Mar.	6	19
	14	10
	22	0
	29	14

Y Sagittarii

	(−2	2)
Mar.	1	13
	7	8
	13	2
	18	21
	24	16
	30	10

U Sagittarii

	(−2	23)
Mar.	2	5
	8	22

U Sagittarii

	d	h
Mar.	15	16
	22	10
	29	4

β Lyræ

	(−3	7)
	(−3	2)
Mar.	5	9
	11	15
	18	7
	24	13
	31	5

κ Pavonis

	(−4	7)
Mar.	9	3
	18	5
	21	7

U Aquilæ

	(−2	4)
Mar.	1	4
	8	4
	15	5
	22	6
	29	6

U Vulpeculæ

	(−2	3)
Mar.	7	20
	15	20

U Vulpeculae

	d	h
Mar.	23	19
	31	19

SU Cygni

	(−1	7)
Mar.	1	15
	5	11
	9	8
	13	4
	17	0
	20	20
	24	17
	28	13

η Aquilae

	(−2	6)
Mar.	6	8
	13	13
	20	17
	27	21

S Sagittae

	(−3	10)
Mar.	6	15
	15	0
	23	9
	31	18

X Vulpeculæ

	h	d
	(−2	1)
Mar.	1	17
	8	1
	14	8
	20	16
	27	0

V Vulpeculae

Minimum

Mar.	10	12

X Cygni

	(−6	19)
Mar.	1	6
	17	16

T Vulpeculae

	(−1	10)
Mar.	4	3
	8	14
	13	0
	17	11
	21	21
	26	8
	30	18

TZ Cygni

Mar.	2	6
	17	0
	31	17

VY Cygni

	h	d
	(−2	14)
Mar.	1	5
	9	1
	16	22
	24	19

VZ Cygni

	(−3	6)
	(−2	12)
Mar.	2	12
	7	6
	12	6
	16	23
	21	23
	26	17
	31	17

Y Lacertae

	(−1	10)
Mar.	5	0
	9	7
	13	15
	17	22
	22	6
	26	13
	30	21

Approximate Magnitudes of Variable Stars on January 1, 1909.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.
X Androm.	0	10.8	+46	27	13.2*d*
T Androm.		17.2	+26	26	9.5*d*
T Cassiop.		17.8	+55	14	8.2*d*
R Androm.		18.8	+38	1	11.7*d*
S Ceti		19.0	− 9	53	8.8 *i*
Y Cephei		31.3	+79	48	12.0*d*
U Cassiop.		40.8	+47	43	8.0 *i*
RW Androm.		41.9	+32	8	13.5*d*
V Androm.		44.6	+35	6	10.6*d*
RR Androm.		45.9	+33	50	<13.5
RV Cassiop.		47.1	+46	53	13.7
W Cassiop.		49.0	+58	1	9.6*d*
RX Androm.		58.9	+40	46	12.2*d*
Z Ceti	1	1.6	− 2	1	10.5 *i*
U Androm.		9.8	+40	11	<13.5
S Piscium		12.4	+ 8	24	<13
S Cassiop.		12.3	+72	5	12.6*d*
U Piscium		17.7	+12	21	11.4*d*
R Piscium		25.5	+ 2	22	<13
RU Androm.		32.8	+38	10	13.4*d*
Y Androm.		33.7	+38	50	<13.5
X Cassiop.		49.8	+58	46	11.0
U Persei		53.0	+54	20	9.0*d*
S Arietis	1	59.3	+12	3	<12.6
R Arietis	2	10.4	+24	35	8.8 *i*
W Androm.		11.2	+43	50	11.9*d*
Z Cephei		12.8	+81	13	<13
o Ceti		14.3	− 3	26	5.5*d*
S Persei		15.7	+58	8	8.8
R Ceti		20.9	− 0	38	12.0 *i*
RR Persei		21.7	+50	49	13.5
U Ceti		28.9	−13	35	11.2*d*
RR Cephei		30.4	+80	42	12.7*d*
R Trianguli		31.0	+33	50	7.0
T Arietis		42.8	+17	6	9.4
W Persei		43.2	+56	34	8.8
U Arietis	3	5.5	+14	25	8.6 *i*
X Ceti		14.3	− 1	26	12.9*d*
Y Persei		20.9	+43	50	8.4
R Persei		23.7	+35	20	9.0
Nov. Per. 2		24.4	+43	34	12.5
R Tauri	4	22.8	+ 9	56	<12.8
W Tauri		22.2	+15	49	10.0*d*
T Camelop.		30.4	+65	57	9.0 *i*
X Camelop.		32.6	+74	56	11.9*d*
V Tauri		46.2	+17	22	11.0 *i*

Approximate Magnitudes of Variable Stars on Jan. 1, 1909—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
R Leporis	4	55.0	−14	57	8.0	RU Virginis	12	42.2	+ 4	42	10.9
V Orionis	5	0.8	+ 3	58	13.5*d*	U Virginis		46.0	+ 6	6	8.1
T Leporis		0.6	−22	2	11.9*d*	RT Virginis		57.6	+ 5	43	8.8
R Aurigae		9.2	+53	28	9.5*d*	V Virginis	13	22.6	− 2	39	12.6*d*
S Aurigae		20.5	+34	4	8.6	R Hydrae		24.2	−22	46	8.2*d*
W Aurigae		20.1	+36	49	11.1*d*	S Virginis		27.8	− 6	41	7.5
S Orionis		24.1	− 4	46	9.0	T Urs. Min.		32.6	+73	56	10.8*d*
T Orionis		30.9	− 5	32	10.4*d*	R Can. Ven.		44.6	+40	2	7.6 *i*
S Camelop.		30.2	+68	45	10.6	U Urs. Min.	14	15.1	+67	15	8.8*d*
RR Tauri		33.3	+26	19	11.4 *i*	S Bootis		19.5	+54	16	8.4 *i*
U Aurigae		35.6	+31	59	10.8*d*	R Camelop.		25.1	+84	17	8.4*d*
Z Tauri		46.7	+15	46	<11.5	R Bootis		32.8	+27	10	11.0 *i*
U Orionis		49.9	+20	10	10.5 *i*	R Coronae	15	44.4	+28	28	8.2*d*
Z Aurigæ		53.6	+53	18	10.0*d*	R Draconis	16	32.4	+66	58	8.3*d*
X Aurigae	6	4.4	+50	15	13.0*d*	T Draconis	17	54.8	+58	14	10.4*d*
V Aurigae		16.5	+47	45	9.0 *i*	— Draconis		54.7	+58	13	11.5
V Monoc.		17.7	− 2	9	11.9*d*	V Draconis		56.3	+54	53	10.0 *i*
R Monoc.		33.7	+ 8	49	11.0	T Herculis	18	5.3	+31	0	11.8*d*
S Lyncis		35.9	+58	0	14.0*d*	W Draconis		5.4	+65	56	9.7*d*
X Gemin.		40.7	+30	23	12.7*d*	X Draconis		6.8	+66	8	9.8*d*
W Monoc.		47.5	− 7	2	10.9*d*	W Lyrae		11.5	+36	38	10.9
Y Monoc.		51.3	+11	22	7.9 *i*	RY Lyrae		41.2	+34	34	10.8*d*
X Monoc.		52.4	− 8	56	7.1	RW Lyrae		42.1	+43	32	12.7
R Lyncis		53.0	+55	28	8.8*d*	RX Lyrae		50.4	+32	42	<13
V Can. Min.	7	1.5	+ 9	2	11.6*d*	Z Lyrae		56.0	+34	49	<13
R Gemin.		1.3	+22	52	11.2*d*	RT Lyrae		57.8	+37	22	<13
R Can. Min.		3.2	+10	11	8.6 *i*	R Aquilae	19	1.6	+ 8	5	9.6*d*
RR Monoc.		12.4	+ 1	17	9.8 *i*	RS Lyrae		9.3	+33	15	11.0
V Gemin.		17.6	+13	17	10.8*d*	RU Lyrae		9.1	+41	8	13.6*d*
S Can. Min.		27.3	+ 8	32	11.2*d*	U Draconis		9.9	+67	7	11.5 *i*
U Can. Min.		35.9	+ 8	37	9.4 *i*	TZ Cygni		13.4	+50	0	9.5 *i*
S Gemin.		37.0	+23	41	<13	U Lyrae		16.6	+37	42	9.9 *i*
T Gemin.		43.3	+23	59	12.0*d*	TY Cygni		29.8	+28	6	13.4*d*
U Puppis		56.1	−12	34	13.0*d*	R Cygni		34.1	+49	58	11.9*d*
R Cancri	8	11.0	+12	2	10.8	RT Aquilae		33.3	+11	30	13.5
V Cancri		16.0	+17	36	11.6*d*	RV Aquilae		35.9	+ 9	42	11.4 *i*
RT Hydrae		24.7	− 5	59	8.6*d*	RT Cygni		40.8	+48	32	7.0 *i*
U Cancri		30.0	+19	14	<12.5	TU Cygni		43.3	+48	49	12.6
X Urs. Maj.		33.7	+50	30	9.2 *i*	χ Cygni		46.7	+32	40	12.5*d*
S Hydrae		48.4	+ 3	27	8.4 *i*	Z Cygni		58.6	+49	46	12.2*d*
T Hydrae		50.8	− 8	46	8.2*d*	S Cygni	20	3.4	+57	42	10.1 *i*
T Cancri		51.0	+20	14	8.8	RS Cygni		9.8	+38	28	8.8
W Cancri	9	4.0	+25	39	9.4*d*	R Delphini		10.1	+ 8	47	11.5 *i*
Y Draconis		31.1	+78	18	<13	SX Cygni		11.6	+30	46	13.8*d*
R Leo. Min.		39.6	+34	58	6.9 *i*	WX Cygni		14.8	+37	8	10.6
RR Hydrae		40.4	−23	34	11.5	U Cygni		16.5	+47	35	10.1
R Leonis		42.2	+11	54	6.4	RW Cygni		25.2	+39	39	8.0
Y Hydrae		46.4	−22	33	7.0	Z Delphini		28.1	+17	7	8.6 *i*
V Leonis		54.5	+21	44	<11.8	ST Cygni		29.9	+54	38	13.1*d*
R Urs. Maj.	10	37.6	+69	18	12.6*d*	Y Delphini		36.9	+11	31	13.4
W Leonis		48.4	+14	15	<12.0	S Delphini		38.5	+16	44	10.7 *i*
S Leonis	11	5.7	+ 6	0	11.8 *i*	V Cygni		38.1	+47	47	10.5
R Comae		59.1	+19	20	<12.2	Y Aquarii		39.2	− 5	12	8.8 *i*
T Virginis	12	9.5	− 5	29	11.0*d*	T Delphini		40.7	+16	2	13.4 *i*
R Corvi		14.4	−18	42	<12	V Delphini		43.2	+18	58	13.8*d*
T Can. Ven.		25.2	+32	3	12.4*d*	T Aquarii		44.7	− 5	31	9.0 *i*
Y Virginis		28.7	− 3	52	10.6*d*	RZ Cygni		48.5	+46	59	13.2
T Urs. Maj.		31.8	+60	2	10.9*d*	X Delphini		50.3	+17	16	12.1*d*
R Virginis		33.4	+ 7	32	10.0*d*	UX Cygni		50.9	+30	2	<13
RS Urs. Maj.		34.4	+59	2	9.2 *i*	R Vulpeculae		59.9	+23	26	12.0*d*
S Urs. Maj.		39.6	+61	38	11.4*d*	TW Cygni	21	1.8	+29	0	11.0 *i*

Approximate Magnitudes of Variable Stars on Jan. 1, 1909—Con.

Name.	R. A. 1900. h	m	Decl. 1900 °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
X Cephei	21	3.6	+82	40	12.2*d*	R Lacertae	22	38.8	+41	51	13.8
RS Aquarii		5.8	− 4	27	9.5 *i*	RW Pegasi		59.2	+14	46	13.4
R Equulei		8.4	+12	23	13.0*d*	R Pegasi	23	1.6	+10	0	10.9*d*
T Cephei		8.2	+68	5	9.5	V Cassiop.		7.4	+59	8	8.0 *i*
RR Aquarii		9.8	− 3	19	13.0*d*	W Pegasi		14.8	+25	44	7.3 *i*
X Pegasi		16.3	+14	2	9.8 *i*	S Pegasi		15.5	+ 8	22	12.4
S Cephei		36.5	+78	10	10.0	ST Androm.		33.8	+35	13	9.0
RU Cygni		37.3	+53	52	7.3	R Aquarii		38.6	−15	50	10.2
RR Pegasi		40.0	+24	33	<13.3	Z Cassiop.		39.7	+56	2	<13.5
V Pegasi		56.0	+ 5	38	12.4*d*	RR Cassiop.		50.7	+53	8	12.4
RT Pegasi		59.8	+34	38	13.0*d*	Z Aquarii		47.1	−16	25	9.0*d*
T Pegasi	22	4.0	+12	3	10.5 *i*	V Ceti		52.8	− 9	31	9.8 *i*
Y Pegasi		6.8	+13	52	14.0	R Casssiop.		53.3	+50	50	8.2*d*
RS Pegasi		7.4	+14	4	14.0	Z Pegasi		55.0	+25	21	9.6
RV Pegasi		21.0	+29	58	11.0*d*	Y Cassiop.		58.2	+55	7	13.6
S Lacertae		24.6	+39	48	9.6 *i*						

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Whitin, Swartz, Mt. Holyoke, Eadie and Harvard Observatories.

GENERAL NOTES.

Sun-Spot Groups. On the 17th of Jan., 1909, four groups of sun-spots were visible on the eastern central portion of the Sun. The penumbra of the largest was very distinct. Clouds, having covered the sky during the earlier portion of the day, it was not until the middle of the afternoon that the Sun's disk was visible at all. Even then, seeing was interrupted by clouds repeatedly passing between the Sun and the Earth. Observations were made with a four inch refractor, power fifty, and a six inch reflector, power about seventy-five. The reflector seemed to show a clearer image than the refractor. I had sun-shades in use; one green in color, and not very dense; the other blue, and much denser. The former was the more satisfactory of the two.

The reflector was made by me during my spare time last month. The whole time occupied in the making of the instrument was less than thirty-six hours, from the commencement of operations until I was observing with the telescope.

ALBERT R. J. F. HASSARD.

Toronto, Canada.

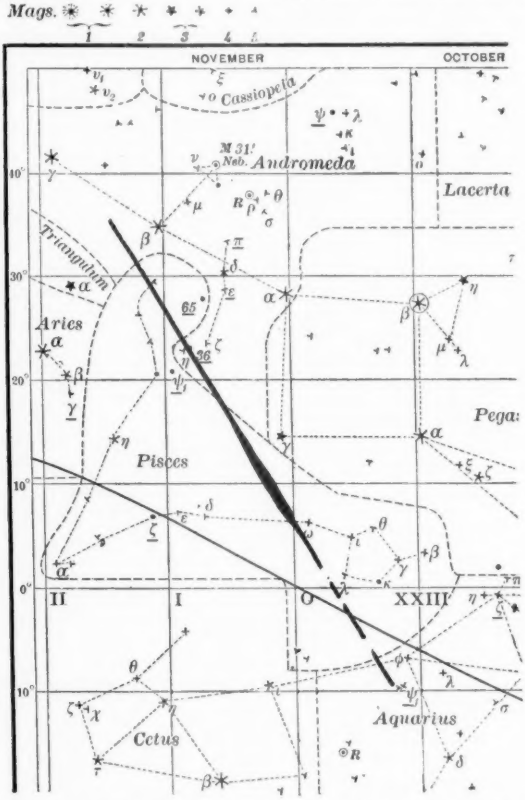
Volume VIII, Publications of the Lick Observatory. The volume referred to in the title, now issuing from the bindery of the State Printing Office, Sacramento, contains heliogravure reproductions of the late Director Keeler's photographs of nebulae and star clusters made with the Crossley Reflector. Other contents are a description of the Crossley Reflecting Telescope by Director Keeler, a list of the nebulae and clusters photographed, a catalogue of 744 new nebulae discovered on the negatives, and new determinations of the positions of the nebulae previously known in the regions of the sky covered. It is hoped that the regular correspondents of the Lick

Observatory can be supplied promptly with copies. The cost of the volume has been unusually high on account of the expensive processes and materials employed. There are 71 full-page heliogravure reproductions, printed by hand press on suitable paper. The price of the volume has been fixed at $5.00, postage paid. Subscriptions may be sent to the University Press, Berkeley, California.

W. W. CAMPBELL.

Mount Hamilton, Jan. 4, 1909.

Meteor Observation. On the evening of November 24, 1908, at about 8:10 P. M., Eastern time, my wife and I observed the brightest meteor I have ever seen. The trail I have plotted on the enclosed map. The meteor moved very rapidly, and illuminated the Earth brilliantly for a second or more. It would seem that the direction of trail precludes the idea of its being an

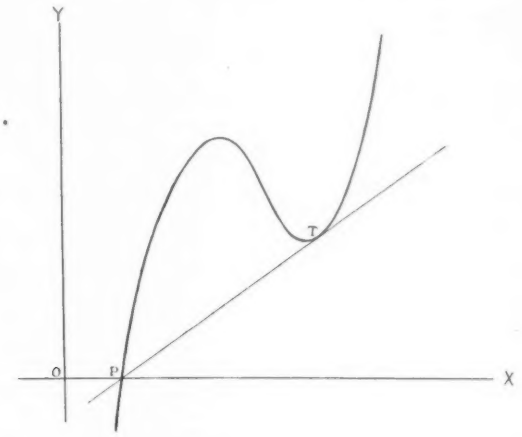


Andromid but would rather lead one to think it a belated Perseid. The meteor made no sound, and I have not been able to get information which would enable me to estimate its height. The meteor disintegrated in a series of flashes.

University of North Carolina,
Chapel Hill, N. C.

A. H. PATTERSON.

A Graphic Determination of the Complex Roots of a Cubic Equation. The above drawing represents the curve developed by the equation $x^3 + px^2 + qx + r = y$. Suppose $a \pm bi$ and c to be the roots of the equation $x^3 + px^2 + qx + r = o$. The curve cuts the x-axis at (c, o) or P. If a straight edge be revolved about P as a pivot until it touches the curve as a tangent at point T, the abscissa of T will be a, and the ordinate $b^2(a - c)$.



Thus the real part of the complex roots may be found immediately, and the coefficient of the imaginary unit from the equation $b^2(c - a) =$ the ordinate of T.

This is easily shown to be true by the following:

$$x^3 + px^2 + qx + r = y \qquad (1)$$

$$\frac{dy}{dx} = 3x^2 + 2px + q$$

Therefore, the tangent at the point (x_1y_1) is

$$y - y_1 = (3x_1^2 + 2\,px_1 + q)\,(x - x_1) \qquad (2)$$

Since $a \pm bi$ and c are the roots of $x^3 + px^2 + qx + r = o$

$$p = -2a - c \qquad q = a^2 + 2ac + b^2 \qquad r = -a^2c - b^2c$$

Putting $x = a$ and substituting these values in (1), $y = b^2(a - c)$.

Putting $x_1 = a$, $y_1 = b^2(a - c)$ and substituting the values found for p and q in (2) and reducing, $y = b^2(x - c)$

which is the tangent to the point $\Big(a_1\, b^2(a - c)\Big)$ or T. Putting $y = o$, $x = c$. Therefore the tangent at T intersects P.

The complex roots of the quadratic equation $x^2 + px + q = o$ may also be graphically determined. If $x^2 + px + q = y$, the abscissa of the minimum point on the parabola is the real part of the complex roots and the square root of the ordinate the coefficient of the imaginary unit.

RUTHERFORD ERWIN GLEASON.

110 Ford Place,
Pasadena, California.

Bands from Aurora or Sunset? In looking through the 1908 index to POPULAR ASTRONOMY, I saw the title, "Auroral Bands." Not having read anything about auroral bands in the number referred to, I looked it up and found Mr. Hassard's note on the beautiful appearance of the sky shortly after sunset August 3, 1908. On August 31, 1907, I saw a sunset with the same bands described by Mr. Hassard. Immediately after sunset a thunderstorm, which dissolved within two hours, became prominent in the northwest. Since that time I have observed several such sunsets with fainter bands, always followed by clouds. This fact suggests that the deep blue bands are merely spaces of sky from which the rays of the setting Sun have been shut off. The pink bands were the regular sunset color.

By referring to the weather map of August 3, 1908, at 8 A. M., I saw a thunderstorm about 400 miles northwest of Toronto in connection with a "low" just north of North Dakota. By 8 P. M. the "low" had moved southeasterly about 300 miles; the thunderstorm probably had also moved about 300 miles, being at sunset abont 100 miles west or northwest of Toronto. By comparing this with the state of affairs at sunset August 31, 1908 in southern Minnesota, they will be found almost identical. This further establishes the theory that those beautiful bands were part of a beautiful sunset and had nothing to do with aurora.

CHARLES F. BROOKS.

Cambridge, Mass.

Sun-Spots seem to be more numerous during the past few weeks than they have been at any other time this year. On the 9th of November, several large groups were visible on different parts of the Sun's surface. None of the individual spots was very large, but the groups were of considerable dimensions. One group consisting of seven or eight small spots covered an area perhaps twenty-five thousand miles in diameter. This group, however, did not contain the largest spot. On the 15th of November, further groups were seen, the revolution of the Sun during the interval between the 9th and that date, having brought them into view.

There have been several nights with very clear skies recently. Last night the sky was quite clear throughout the whole night. With my nine and one half inch reflector, the shadow of Saturn's ring on the ball of the planet was very clearly defined. The black sky in between the ball and the inner edges of the ring, to the east and west of the planet, was markedly apparent. Titan was plainly visible; and a number of bright points of light, most probably other satellites; as many as four or five others. Very likely these could have been identified had I consulted an ephemeris. It would have been difficult otherwise to distinguish them from faint stars. The appearance of Saturn's system of satellites is not such as to encourage a careful examination being made of them. But the appearance of the planet and with its nearly always visible satellite Titan, is worth all the trouble necessary to observe it.

Last night I looked at many objects through the nine and one half inch instrument. The other most impressive object was the nebula in Orion. It almost resembled a distant house on fire. The four stars of the trapezium were clearly defined; and a little way off a single star wrapped in nebulosity was interesting. The Andromeda nebula was clearly seen, and bright, with an intensity of the brightness appearing in the central portion.

I should like to be placed in communication with any persons who are desirous of doing practical observational work in astronomy this winter. If such

will communicate with me, some systematic work may be achieved. Astronomers, apart from those so professionally engaged, have been inactive too long.

Toronto, Canada, November 21, 1908. ALBERT R. J. F. HASSARD.

Ephemeris for Physical Observations of the Sun.

Greenwich Mean Noon.							Greenwich Mean Noon.						
1909.	P.		D.		L.		1909.	P.		D.		L.	
	°	′	°	′	°	′		°	′	°	′	°	′
Jan. 2	+ 2	1	−3	10	209	38	July 5	− 0	55	+3	26	287	49
6	− 0	25	3	44	143	47	10	+ 1	22	3	57	221	39
11	2	50	4	16	77	57	15	3	37	4	26	155	29
16	5	13	4	46	12	7	20	5	50	4	54	89	19
21	7	31	5	14	306	16	25	7	59	5	20	23	10
26	9	45	5	40	240	26	30	10	3	5	43	317	2
31	11	52	6	2	174	37	Aug. 4	12	3	6	4	250	55
Feb. 5	13	53	6	22	108	47	9	13	56	6	23	184	48
10	15	47	6	39	42	56	14	15	44	6	39	118	42
15	17	32	6	53	337	6	19	17	25	6	52	52	37
20	19	9	7	4	291	15	24	18	58	7	2	346	33
25	20	37	7	10	205	25	29	20	24	7	10	280	29
Mar. 2	21	56	7	14	139	32	Sept. 3	21	41	7	14	214	26
7	23	5	7	15	73	40	8	22	50	7	15	148	25
12	24	4	7	12	7	47	13	23	50	7	13	82	23
17	24	53	7	6	301	53	18	24	41	7	8	16	23
22	25	32	6	56	235	57	23	25	22	6	59	310	23
27	26	1	6	44	170	1	28	25	54	6	48	244	25
Apr. 1	26	19	6	29	104	4	Oct. 3	26	15	6	34	178	26
6	26	26	6	10	38	5	8	26	25	6	16	112	28
11	26	23	5	50	332	5	13	26	25	5	56	46	30
16	26	8	5	26	266	4	18	26	13	5	33	340	33
21	25	42	5	1	200	1	23	25	50	5	8	274	37
26	25	5	4	32	133	58	28	25	15	4	40	208	40
May 1	24	17	4	3	67	53	Nov. 2	24	28	4	10	142	44
6	23	19	3	32	1	47	7	23	29	3	37	76	49
11	22	9	2	59	295	41	12	22	19	3	4	10	54
16	20	50	2	25	229	33	17	20	57	2	28	304	59
21	19	20	1	50	163	24	22	19	24	1	52	239	5
26	17	42	1	15	97	15	27	17	41	1	14	173	11
31	15	55	0	39	31	5	Dec. 2	15	47	+0	37	107	17
June 5	14	1	−0	2	324	55	7	13	45	−0	2	41	24
10	11	59	+0	34	258	44	12	11	35	0	40	335	31
15	9	53	1	10	192	33	17	9	19	1	19	269	39
20	7	41	1	45	126	22	22	6	58	1	56	203	47
25	5	28	2	20	60	11	27	4	34	2	33	137	55
30	− 3	11	+2	53	354	0	32	+ 2	8	−3	8	72	4

The position-angle of the Sun's axis, P, is the position-angle of the N. end of the axis from the N. point of the Sun, read in the direction N., E., S., W. In computing D (the heliographic latitude of the center of the Sun's disk), the inclination of the Sun's axis to the ecliptic has been assumed to be 82° 45′, and the longitude of the ascending node for 1909.0 to be 74° 29′.4. In computing L (the heliographic longitude of the centre of the Sun's disk), the Sun's period of rotation has been assumed to be 25.38 days, and the meridian which passed through the ascending node at the epoch 1854 Jan. 1, Mean Noon, has been taken as the zero meridan.—*The Observatory*, January, 1909.

Comet Morehouse. During the month of November the comet did not seem to go through such periods of great activity as in the two preceeding months, however, it has by no means been quiescent.

The most interesting photographs which I secured in this period were those on the eleventh, fifteenth, and sixteenth. The remarkable thing shown in the first of these (Nov. 11) is the undulating form of the tail. Prof. E. E. Barnard has commented upon this in the *Astrophysical Journal* (Vol. 28 No. 5). It is very noticeable in his photograph of October 30. In "*Physical Astronomy*—Studies from photographs of the Morehouse Comet (1908 *c*) at the observatory of Juvisy (France) by MM. Baldet and Quenisset," is the following paragraph: "Upon the majority of the plates the principal tail is undulated but upon five and particularly upon those of Nov. 1 we see two tails more brilliant, which cross alternately. When one places in a stereoscope two of these plates taken at an interval of an hour or two he finds these tails wound in a spiral form around each other. Upon the photograph of Nov. 1 we counted eight spirals." (Published at Paris, Nov. 30, 1908).

In a negative taken Nov. 11, I counted eight of these pulsations. Outside of this the comet seems perfectly normal. The head is bright and small giving off a few short spurs. The tail fades gradually from the coma and extends to the greatest length of any of the photographs obtained.

My best telescopic view of the comet was obtained on the night of Nov. 15. The two main branches near the head gave the appearance of a thin white veil draped over a star. Farther down the stronger of the two main divisions divided again into several rays, the stronger of these continuing to divide and finally turned abruptly to the north. On the following night Nov. 16, the entire aspect of the comet had changed. The coma was much stronger both visually and photographically. The tail shows strong signs of pulsations and is strikingly similar to the photograph of Oct. 15, 8:20—9:31 (T. M. D. P.) taken at Juvisy (France). The displacement of the tail in the November plate is south while it is toward the north in the French photograph. In both views a faint straight tail can be seen to continue directly from the head.

These negatives were taken with a three inch portrait lens kindly loaned by Prof. E. E. Barnard of Yerkes Observatory. The lens did not give good star images around the outer portions of the field hence the widening of the star trails in the enlarged picture.

D. W. MOREHOUSE.

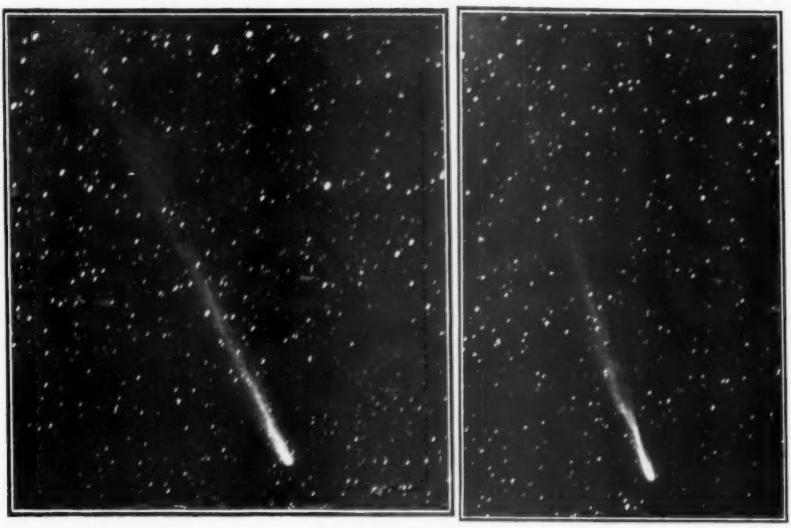
Drake University,
Des Moines, Iowa.

Micrometric Observations of Comet *c* 1908 (Morehouse).

1908	C.S.T.	Comet's Apparent R.A. h	m	s	Decl. °	′	″	Comparison Star.		
Sept.	2.5	3	22	01.1	+66	56	11.1	Photographically.		
Sept.	28.44798	22	30	29.34	75	25	36.4	B.D.	969	+74
Oct.	1.43022	21	07	33.01	71	20	38.2	B.D.	1046	71
Oct.	6.68917	20	11	49.74	64	15	57.0	B.D.	1423	64
Oct.	11.32423	19	42	38.2	56	44	14.0	B.D.	2291	56
Oct.	13.34367	19	34	01.94	53	22	08.3	B.D.	2269	53
Oct.	29.33754	19	00	29.32	26	36	51.7	B.D.	3437	26
Nov.	2.38648	18	56	50.9	20	30	43.9	B.D.	3420	20
Nov.	8.29527	18	53	46.78	13	11	52.9	B.D.	3827	13
Nov.	10.34649	18	52	56.48	10	34	36.2	B.D.	3741	10
Nov.	11.34784	18	52	42.72	+ 9	42	16.4	B.D.	3940	+ 9

PLATE IV.

Nov. 15. $6^h\ 45^m$—$8^h\ 40^m$



Nov. 11 $6^h\ 30^m$—$8^h\ 0^m$ Nov. 16 $6^h\ 20^m$—$8^h\ 20^m$

PHOTOGRAPHS OF COMET *c* 1908
By D. W. Morehouse

These observations were made with a Warner & Swasey filar micrometer attached to an 8¼" equatorial. The measurements were taken according to Chauvenet's second method.

Drake University, D. W. Morehouse.
Des Moines, Iowa.

The Great Disk for Mt. Wilson a Failure. It is now known that the casting of the great disk, one hundred inches in diameter for the Solar Observatory on Mt. Wilson, California, has proved a failure. The working of the big glass had proceeded nearly to a finish when it was learned that it contained flaws that made it unfit for telescopic uses.

Professor Geo. E. Hale, the Director of the Solar Observatory on Mt. Wilson, is at a loss to know why the specialists in charge of the casting and the testing of the great lens did not discover its defects before it was shipped from France.

If the flaws were at all prominent, is it not also a wonder that those who were grinding the lens did not discover them sooner?

When large lenses are cast and annealed, it sometimes happens that interior parts are left in a state of unequal strain, so that when the constraining outer parts are removed in the process of grinding, the whole lens will fly in pieces like the breaking of a Rupert drop. This once happened when the Clarks were grinding a large lens. But they knew the strained condition of that piece of glass by tests made beforehand, and they would not work it on their own responsibility, but finally did so on the responsibility of others, with the result already stated.

In the cases of strain well-known tests before grinding begins will detect it, but in the case of flaws and bubbles, if they are not prominent or obtrusive it is not an easy problem to detect them before the glass is worked near them or the polishing reveals them.

Professor Hale has decided that a new disk will be necessary, and that the company from which the defective one was purchased will have to stand the loss. This means a delay that will be regretted by astronomers who are interestedly waiting to know what a hundred inch glass can do for their science.

Probably a New Planet beyond Neptune. Professor William H. Pickering of the Harvard College Observatory has announced that a planet belonging to the solar system, and hitherto unknown, lying beyond the orbit of Neptune is likely to be found in the year 1909. Professor Pickering has the courage to name its approximate place, as Right Ascension $7^h\ 47^m$, Declination $+21°$.

With a little thought, our popular readers will remember that a planet beyond Neptune does not belong to that group of small planets we call Minor Planets or Asteroids, but that such a supposed planet would belong to the major group of which Jupiter is the largest, and Saturn, Uranus and Neptune are also members.

To predict the place of an unknown planet on the outermost confines of the solar system is a severe task which is likely to be accomplished only by the ablest mathematicians who are astronomers as well. This is a problem like that noted one solved by Adams and LeVerrier which quickly led to the discovery of the planet Neptune in 1846. The path of Uranus was slightly disturbed by some outside attraction. These noted astronomers, after long and

tedious computation believed it was an outside planet that made the disturbance, and they told observers where to look for it with the telescope (it is so far away it cannot be seen by the naked eye), and Galle of Berlin soon found it.

Now, it is known that Neptune is disturbed in its orbit around the Sun in a similar manner, and Professor Pickering is sure enough of the place of the remote outside wanderer to point to a place in the heavens where another new planet may be found. If his predictions shall be verified in 1909, it will probably be the most remarkable discovery, in astronomy of its kind, in more than fifty years.

This view of this problem in no way lessens the great honor due to Asaph Hall in discovering the faint satellites of Mars, or that due to E. E. Barnard in finding the fainter fifth satellite of Jupiter, or the noble discoveries of C. D. Perrine and W. H. Pickering which added other new satellites to the planets Jupiter and Saturn. These famous discoveries were triumphs chiefly of visual skill or by the aid of the photographic plate, while the former ones were due to the genius and rare power of mathematical analysis.

The Astronomical and Astrophysical Society of America.—The number of *Science* published December 11, 1908, contained a full account of the meeting of the society held at Put-in-Bay, during the past summer, giving abstracts of many of the papers.

We reprint for the benefit of our readers a few of the abstracts as they appeared in that paper.

A Possible Third Body in the System of Algol: R. H. CURTIS.—Spectroscopic determinations of the center of mass velocity of the eclipsing stars of Algol indicate strongly that three bodies enter into this system about the center of mass of which the eclipsing pair revolve in a nearly circular orbit with a radius of not less than 89,000,000 km., a period of 1.899 years and an epoch of minimum radial velocity at the date, 1901.85.

The variations observed in the eclipse period of this star, as well as those suspected in the eccentricity, are possibly largely due to perturbations arising in such a system.

As a consequence of the orbital motion of the center of mass of the eclipsing pair a variation in the time of light minimum with a range of ten minutes and a period of 1.899 years should be shown by photometric observations.

A New Form of Stellar Photometer; E. C. PICKERING.—In this new form of stellar photometer, an artificial star is formed by allowing a small electric light, run by a storage battery, to shine through a minute hole, placed in the focus of a small auxiliary telescope. This telescope is placed at right angles to the main telescope and a piece of plane glass set at an angle of 45° reflects the artificial star into the eyepiece. A piece of opal or ground glass is placed over the hole, and the light of the artificial star is varied by moving the electric light, along the axis of the small telescope, by a known amount. The scale of the instrument accordingly depends on the law of the square of the distances, instead of on the laws of polarized light, or on the empirical law found for wedge photometers.

On the Character of the Light Variations of α Herculis: FRANK SCHLESINGER.—This star has long been thought to be an irregular variable with a period of 35 to 40 days and with rapid fluctuations near minimum. Frost and Adams have shown it to be a spectroscopic binary. In the spring of this year it was placed upon the observing program of the Mellon spectograph of the Allegheny Observa-

tory and Professor Pickering kindly agreed to have it observed simultaneously at Harvard with the photometer. Our spectrograms were measured and reduced by Mr. Baker, who deduced a period of 2.05 days for the velocity variations, very different from that assigned to the light variations. In discussing these observations with Mr. Baker it occurred to us that the star might be an Algol variable. The character of the spectrum and the form of the orbit (especially the small eccentricity) and most of the observations concerning its light, are in conformity with this idea. Mr. Wendell's observations at Harvard showed that this surmise is correct, and further proved the existence of a secondary minimum, so that the star is more properly of the Beta Lyræ type than of the Algol type. With the help of a diagram it may be shown how all the observed phenomena concerning this star can be explained and how the erroneous conclusions concerning the period and the fluctuations at minimum arose. The case is interesting as showing the intimate connection between photometric and spectrographic observations, the true charcter of the light variations being first indicated by the latter.

Measurement of Starlight with a Selenium Photometer; JOEL STEBBINS.—This paper presents the results of experiments on the use of selenium in stellar photometry. It is well known that the crystalline form of selenium decreases its electrical resistance when exposed to light. The method is to cast an extra-focal image of a star upon a selenium surface, and note the effect by means of a galvanometer. Using a 12-inch telescope, it has been possible to measure first and second magnitude stars with about the same accuracy that is obtained in visual methods. Tests with brighter artificial lights give a probable error of less than one per cent for a single measurement.

In the course of a year the sensibility of the apparatus has been increased one hundredfold, and it is hoped that further improvements in the elimination of disturbing factors will produce extremely accurate results.

Effect of Increasing the Slit Width on the Accuracy of Radial Velocity Determinations: J. S. PLASKETT.—Experiments at Ottawa have shown that exposure time is almost proportionally decreased with increase of slit width to about 0.075 mm. Six spectra of β Orionis were made for each of four slit widths—0.025, 0.038, 0.050 and 0.075 mm —at three different dispersions. The accidental errors of setting, as measured by the probable errors of the velocity from a single line obtained from the six plates in each series, are only slightly increased, scarcely at all in the higher dispersion, by increase in slit width to 0.075 mm. A further discussion shows that the increase of systematic error, so far as it may be determined from the limited number of plates, is also small with high dispersion, although quite marked for a slit 0.075 mm. wide with low dispersion. These somewhat unexpected results show that for stars with single lines the slit may be much widened without much loss of accuracy and with a considerable saving in exposure time.

Some Observations of Double Stars.—The following observations of double stars were made with the 6½-inch Clark refractor of my observatory. From the time the telescope was set up on July 12, 1906, to the latter part of 1907, I found independently some 250 double stars (generally under 10″ distance). Their positions were noted with the coarse circles, and the magnitudes, position angles, and distances were estimated with the eye, on a single night. By the slow motion in declination the position of the hour circle could be noted in the field and from this the position angle was judged. The pair was then identified by the help of Prof. Burnham, or in later observations from his General Catalogue. Some of the pairs are not yet identified. A few of the more difficult identified pairs with the rough positions and eye estimates at the time of observation are given in table 1 in order to place on record what may be actually

found or seen with a 6½-inch aperture by an inexperienced amateur observer without verniers and micrometer.

In order to compare the observations with actual positions and measures, table II gives the positions of the same pairs for 1880 taken from Burnham's Catalogue, together with their probable positions, angles and distances, as estimated from Burnham's diagrams, or actual later measures, or averages of such where the pair is fixed.

All the pairs given in the tables were found independently with the exception of ξ Scorpii.

It may be added that the 6½-inch objective used in making the observations is the work of Mr. Carl A. R. Lundin of the Alvan Clark and Sons Corporation

TABLE I.

No. G. C.	D. S.	T. O.	R. A. h m	Dec. ° ′	Mag.	P. A. °	D. ″	Remarks
260	0Σ12	1907.48	0 25	53 45	4	160	0.5	
6948	Σ1863	1907.54	14 35	52 5	6	90	0.6	Nearly right
7332	0Σ298	1907.21	15 32.5	39 50	7, 8	180	1.2	
	A & B					100 or		
7487	ξ Scorp.	1907.21				280		Well under 1″
						150	8	
7943	β126	1907.21	17 15	−17 55	7, 9, 13	270	1.8	
						145 or		
8038	Σ2173	1907.47	17 26	−58	5	325	0.4	
8271	Hu235	1907.68	17 54	46 2	6, 9	260	1.5	
						0 or		
9565	0Σ383	1907.8	19 41	40 30	7, 9	180	0.8	
						40	20	Just separated
10041	0Σ403	1907.8	20 13	41 57	7, 7.5, 10	165	0.9	with power of 167
	A & B					0 or		
10588	β155	1907.56	20 49	51	7	180	0.6	
12125	β1147	1907.67	22 58	42	4, 7	180	0.6	
12325	β718	1907.56	23 17	31 10	4	135	0.6	
						0 or		
12432	β720	1907.48	23 29	30 40	4	180	0.4	

TABLE II.

No. G. C.	D. S.	T. O.	R. A. 1880 h m s	Dec. 1880 ° ′	Mag.	P. A. °	D. ″	O
260	0Σ12	1902.51	0 25 9	53 52	5.6, 5.4	152.7	0.58	Hu 2n [a]
6948	Σ1863		14 34 15	52 6	7.1, 7.4			
7332	0Σ298	1906.22	15 31 46	40 12	7, 7.3	187.9	1.16	A 2n
7487		1906 38				68.7	0.23	A 4n \ 36
		1907.30				102.8	0.31	A 2n / in. [b]
						139	11.6 [c]	
7943	β126		17 12 59	−17 38	6.4, 7.5, 11.7	262	1.9	
8038	Σ2173	1907.47	17 24 5	−58	5.8, 6.1	315	0.5 [d]	
8271	Hu235	1903.75	17 53 41	45 52	6.7, 9.3	265.4	1.69	Bies-brœck 3n
9565	0Σ383	1903.54	19 38 52	40 26	7, 8.5	23.0	0.95	Doo 2n
10041	0Σ403	1901.97	20 10 13	41 44	7, 7.2, 9.5	170.7	0.76	Doo 3n [e]
						32.9	11.97	Hu 3n [f]
	A & B							
10588	β155	1905.69	22 57 5	42 7	5, 8.7	339	0.47	A 1n [g]
12325	β718	1899.26	23 11 3	31 9	5, 8.7	86.8	0.59	A 2n
12432	β720	1906.5	23 28	30 40	6, 6	173.6	0.36	A 2n [h]

[a] Angle increasing.
[b] These are given for 1907.21: 99°.5, 0″.3.
[c] Fixed average of measure.
[d] Estimate from diagram.
[e] A and B.
[f] B and C.
[g] Angle and distance increasing.
[h] Angle increasing.

The following abbreviations are used:

D = Distance.
Dec. = Declination.
D. S. =Double Star (ordinary designation).
Mag. = Magnitudes of components; given as single where pair was not separated.
No. G. C. = Number of the pair in the General Catalogue.
O = Observer.
P. A. = Position Angle.
R. A. = Right Ascension.
T. O. = Time of observation or measure.
A = Aitken.
Doo = Doolittle.
Hu = Hussey.
2n, 3n = Two nights, three nights.

Syracuse, N. Y. E. D. Roe, Jr.

Resume of Sun-Spot Observations, 1908.

Month	No. of Obs.	N. of Equator No. Groups	N. of Equator Av. Lat.	S. of Equator No. Groups	S. of Equator Av. Lat.	Av. No. at each Obs.	New Groups
January	18	4	+12.8	13	−8.0	2.7	17
February	18	6	13.4	8	12.2	2.6	13
March	16	4	8.2	7	11.6	2.2	10
April	20	3	7.4	13	13.2	3.0	18
May	15	6	7.8	11	10.2	2.8	13
June	13	5	5.1	5	13.6	3.2	7
September	8	3	6.8	4	11.4	4.0	7
October	16	7	7.2	5	14.5	2.5	11
November	18	7	6.7	4	11.6	2.4	10
December	11	4	+ 5.2	6	−17.3	2.1	9

Average number at each observation, 2.69.
Average latitude of spots north of equator, +8°.1.
Average latitude of spots south of equator, −12.3.

In the resumé a group appearing upon the eastern limb was counted as "new," although it may have been visible upon the western limb at a previous time.

The Sun was observed several times when no spots were seen:—January 27, 28, February 18, March 25, October 16, 17, 27.

Observations were made by the writer with the eight-inch equatorial, except on three days in January, when a portable telescope was used. The image of the Sun was projected upon Thomson's Disks, from which approximate latitude and distance from the center can be read at once for each group.

Anna Laura Oathout.

Mount Holyoke College Observatory.

New Southern Observatory of the Carnegie Institution. The December number of the *Observatory* published an interesting letter from Professor Lewis Boss, who has just left for San Luis, Argentina for his second expedition accompanied by five assistants, and taking the Olcott meridian-circle, clocks, chronograph, etc. They plan to make about 8,000 observations. We quote a few paragraphs with reference to the work at the Southern Observatory, and its relation to that at Dudley Observatory, Albany, N. Y.

"The work I am doing is carried on as the Department of Meridian Astrometry of the Carnegie Institution. The Dudley Observatory freely adds its own resources to those of the Department, and the headquarters of the Department

are located at that Observatory in Albany. The two organizations are practically one, and are under the same direction.

The object of the Department is to ascertain the motions of the stars so far as they can be deduced from published meridian-observations of precision supplemented by special observations made at the present time or to be made in the near future. The stars selected for investigation are such as were accurately observed previous to 1850, excluding for the most part zone-observations like those of Bessell and Lalande. All stars supposed to be brighter than the seventh magnitude are also included, whether they have been accurately observed in the past or not. The entire list includes about 25,000 stars scattered over the entire sky from the North to the South Pole.

Particular attention is paid to the systematic errors of the various star-catalogues. This involves, as a matter of course, researches upon the positions and motions of the standard stars, as an indispensable basis. A Catalogue of 627 Primary Standard Stars was produced five years ago and published in the *Astronomical Journal*. More recently the Department has prepared a catalogue of 6188 stars, selecting for this purpose all stars, in either hemisphere, that are brighter than the sixth magnitude, together with many fainter stars for which the motions could be computed with a considerable degree of accuracy. The manuscript has been ready for several months, and is now in the hands of the printer. This work is likely to appear in the course of 1909.

These works have been produced through a bureau of computations in Albany, and to produce works like these constituted the main object of the Department. But the projected works of observation which form the second divison of our work are also extensive. It is proposed to contribute by observation a new fundamental determination of star-places with the Olcott meridian-circle of Albany. It is also the intention to observe a large number of our selected stars, in order to be able to compute more accurate proper motions. This virtually means that we intend to observe all the stars of our list that are south of $-30°$ of declination. These will include all of the Lacaille stars.

In order to carry out our plans as to the fundamental stars, as well as in relation to all other stars now much in need of reobservation, it has been decided to use the Olcott meridian-circle alternately in the two hemispheres. Already over 14,000 observations have been secured at Albany. The instrument will shortly be taken down and set up in San Luis, Argentine Republic, in approximate longitude $66° 21'$, latitude $-33° 18'$. Accompanied by Prof. Richard H. Tucker, of the Lick Observatory, who is to have charge of the new observatory, and by Mr. W. B. Varnum, many years assistant at the Dudley Observatory, I sailed from New York on August 20. While in Argentina his expedition was brought to the attention of the Government and people, who manifested a warm interest and appreciation. We were very effectively aided in every possible way both by the National and Provincial Governments. The site selected at San Luis (about 500 miles west of Buenos Aires) is situated on national property, and is admirably adapted to the purpose. The elevation above sea-level is about 800 metres.

The meridian-circle house will be about 22×23 feet, with extensions north and south for collimators. There will be a small house to contain the photometer. Quarters and offices for the observers will be provided in a building one story high, built of brick around an interior court, all to be ready for occupancy about February first."

Errata. We apologize for a typographical error in page 638, line 20 of Mr. Fath's article December number, which entirely changed the sense of the sentence. For "this would materially change" should have read "this would *not* materially change."

We would call attention, also to another error, but one which occurred in the Lick Observatory Bulletin, from which we reprinted. In the foot-note, page 635, the citation should read—*Astron. Nach.* 79, 327, 872.

Also on page 586 of the same number, with respect to the magnitude of V Cassiopeia. On the first of that month, it was between the 9th and 10th magnitude, having risen to visibility in the telescope in the beginning of October.